Vol. XLIX. SEPTEMBER, 1923. No. 7.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

REPORTS, PAPERS, DISCUSSIONS, AND MEMOIRS

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ADDRESS AT THE ANNUAL CONVENTION IN CHICAGO, ILLINOIS, JULY 11, 1923

By Charles F. Loweth,* President, Am. Soc. C. E.

There is a Constitutional provision that the President of the Society shall present an address at each Annual Convention. After consideration of how this requirement could best be complied with on this occasion, it seemed quite opportune to review some aspects of the affairs of the Society, both in retrospect and prospect. To do this will obviously result in repeating some matters which may be well or even better known to many; to look forward may provoke renewed interest in the Society's aims and activities. It is hoped that what follows may not appear to be a needless repetition of facts, now more or less of record, but may help to a better understanding of the problems with which the Society is confronted and be helpful in their wise solution.

The American Society of Civil Engineers was founded November 5, 1852. It has therefore just passed its Seventieth Anniversary. In these seventy years, much water has gone over the dam of engineering practice; much of the whole field of engineering has been revolutionized in this period, both as to materials of construction and as to practice. It is safe to assert that the Society and the rank and file of its membership have contributed in large measure to, and have had a great degree of responsibility for, the remarkable progress of these seventy years.

It is interesting to note the date of the founding of National engineering and architectural societies in various countries:

The Institution of Civil Engineers of Great Britain was founded in 1818 and incorporated in 1828.

The Institution of Civil Engineers of Ireland was founded in 1835 and incorporated in 1877.

The Royal Institute of British Architects was founded in 1837.

The Institution of Mechanical Engineers was founded in 1847.

Koninklijk Instituut van Ingenieurs, (Holland) was founded in 1847.

Oesterreichischer Ingenieur- und Architekten-Verein, (Austria) was founded in 1848.

Société des Ingénieurs Civils de France, was founded in 1848.

American Society of Civil Engineers, was founded in 1852.

The American Institute of Architects was founded in 1857.

The Iron and Steel Institute was founded in 1869.

The American Institute of Mining and Metallurgical Engineers was founded in 1871, the organization meetings of this Society having been held in the rooms of the American Society of Civil Engineers.

The American Society of Mechanical Engineers was founded in 1880.

* Chf. Engr., C., M. & St. P. Ry., Chicago, Ill.

The American Water Works Association was founded in 1881.

The American Institute of Electrical Engineers was founded in 1884.

The older local engineering organizations of the United States are the Franklin Institute, founded in 1824, the Boston Society of Civil Engineers, in 1848, and the Civil Engineers Club of the Northwest, now the Western Society of Engineers, founded in 1869.

It will be interesting to review the early efforts to found a National engineering society in this country. The founding of this Society in 1852 was preceded by earlier efforts; more than twelve years previously "a highly respectable meeting of the profession" was held in Augusta, Ga., of which, unfortunately, no record remains. At this meeting, the formation of a National engineering society was urged, and an appeal to that end was sent out to a widely scattered group of men, calling a convention of civil engineers of the country. In response to this call, forty engineers from nine of the Seaboard and Gulf States and from Illinois and Missouri met in Baltimore, Md., on February 11, 1839. At this meeting, it was decided to organize a Society of Civil Engineers of the United States. Mr. Benjamin H. Latrobe, of Baltimore, a bridge engineer of great note, was elected President and Mr. J. F. Houston, of Pennsylvania, was made Secretary. A representative committee of seventeen, from eleven States, so elected that "different portions of the Union may be represented so far as is practicable," was appointed to prepare a Constitution and take other steps toward forming a permanent society. Two of these gentlemen were later members of this Society. A few members of this Committee met in April, 1839, at the rooms of the Franklin Institute in Philadelphia, Pa. A draft of a constitution for a society was agreed on, and later submitted to the remaining members, but failed of approval, as only seven of the seventeen members voted in favor of it. It is worthy of note that the name of the proposed society, as stated in the draft of the Constitution, submitted by this Committee, was identical with the present name of the Society, and that architects were to be admitted only as Associates. This effort, however, seems to have been born out of time, for nothing further resulted; however, it doubtless paved the way for the more successful effort thirteen years later, in November, 1852, when this Society was formed.

The founding of this Society was the result of a call by a few New York engineers, dated October 23, 1852, for a meeting to be held November 5, in New York, N. Y., to organize a "Society of Civil Engineers and Architects." At this meeting, it was resolved that an organization should be formed and incorporated, the name of which should be "The American Society of Civil Engineers and Architects." A draft of a Constitution was submitted and approved, and remained in force without change until 1868. It fixed the permanent place for the transaction of the business of the Society as New York, N. Y., and provided for one grade of membership only, to which were eligible "Civil, Geological, Mining and Mechanical Engineers, Architects and other persons who by profession, are interested in the advancement of science." Officers were elected, the first President being the late James Laurie, who

remained in office until after the re-organization of the Society, in 1867. At this meeting was approved the draft of an address to be sent to those engineers and architects of the United States, who were considered by the Board of Direction as eligible for membership, making an appeal for support for the new society. A part of this appeal is as follows:

"It will be admitted that no point in our country offers the facilities for rendering such a society of practical benefit to the public as well as to its own members as the city of New York, and so long as this city retains its present commercial importance, so long it will be a center around and within which there will accumulate by a natural law practical commercial and professional information not elsewhere to be sought, and which, embodying the elements of successful enterprise, may be regarded as a fund of valuable data, equally valuable to the man of science and to the political economist. Much of this information, is, from its nature, unwritten, but is entirely accessible, and, under the auspices of a society formed for that purpose, could be rendered available to such members as may desire the benefit of it.

"The Constitution of the Society declares that it has for its object:

"The professional improvement of its members, the encouragement of social intercourse among men of practical science, the advancement of engineering in its several branches, and of architecture, and the establishment of a central point of reference and union for its members.

"Among the means to be employed for attaining these ends shall be periodical meetings for the reading of professional papers, and the discussion of scientific subjects, the foundation of a library, the collection of maps, drawings and models, and the publication of such parts of the proceedings as may be deemed expedient.

"Civil, geological, mining and mechanical engineers, architects and other persons who, by profession, are interested in the advancement of science, shall be eligible as members.

"It is anticipated that the union of the three branches of civil and mechanical engineering and architecture will be attended by the happiest results, not with a view to the fusion of the three professions in one; but as in our country, from necessity, a member of one profession is liable at times to be called upon to practice to a greater or less extent in the others, and as the line between them cannot be drawn with precision, it behooves each, if possible, to be grounded in the practice of the others; and the bond of union established by membership in the same Society, seeking the same end, and by the same means, will, it is hoped, do much to quiet the unworthy jealousies which have tended to diminish the usefulness of distinct societies formed heretofore by the several professions for their individual benefit.

* * * * * *

"It is scarcely necessary in this place, even did space permit, to enlarge on the many advantages which may be anticipated to flow from the judicious management of such a society as the one we have organized."

The first meeting at which the Society actually got to work as such appears to have been January 5, 1853. However, only eight members were present at that meeting.

Even in 1852, the time was premature for the formation of a National civil engineering society; the early records state that, although in 1853 there were eight regular meetings and a membership of fifty-five, the average attendance at each meeting was only six, and, in 1854, with six meetings and no increase of membership, the average attendance per meeting was less than six. This was a discouraging situation and, with the hope of

bettering it, the dues were reduced from $10 to $5 for resident members and from $5 to $3 for non-resident. The report of the Board of Direction states that it was induced to make the reduction "in order to render membership less onerous, with the hope that new members might be induced to seek a connection with the Society," and, further, that "the labors of the members more than their money is wanted to make the Society useful." There appear to have followed only two or three meetings in the early part of 1855. During these two years and a few months, the Society had no rooms it could call its own, which fact was thought at the time to be in some measure responsible for its lack of growth.

Then follows a lapse of about twelve and one-half years, during which the Society, although it did not disband, appears to have hibernated. At the call of the President, Mr. James Laurie, who still retained office, a meeting was called for October 2, 1867 to "take such steps as may be necessary to resuscitate the Society." At this meeting a committee was appointed to prepare a "plan for the revival of the meetings." At a meeting held a week later, this Committee reported and, among other things, recommended the acceptance of an offer for the use of certain rooms at an annual rental of $400, and their furnishing at a cost of $600. The next meeting, a month later, on November 6, 1867, was the first held by the Society in rooms devoted exclusively to its use. At this meeting the accumulated dues of members during the previous twelve or more years were remitted, and the annual dues were increased to $10 for resident and $5 for non-resident members. During this intermission in the activities of the Society, its financial affairs seem to have prospered. In 1854, the Treasurer had $266.93 on deposit in a savings bank which, on the re-organization of the Society, had grown to $497.57, and the President turned over $558.25, representing the dividends on five shares of New York Central Railroad stock which the Society had acquired in March, 1855. At the following meeting, December 4, 1867, while only nine members were present, fifty-four new members were elected. This meeting was the beginning of the custom of holding regular semi-monthly meetings on the first and third Wednesdays of each month, a practice which prevailed until the formation of the New York Section in 1921, since which time the Society meetings have been held monthly. On March 4, 1867, by a vote of seventeen to four, the name of the Society was changed to the "American Society of Civil Engineers." Through oversight, incorporation was not effected until April 17, 1877.

The record shows that in the premature efforts made in 1839, and throughout the years 1853-54-55, and again when the infant Society was being revived in 1867, there were uppermost in the minds of the men working for the formation of this Society two outstanding principles: First, that it should be broadly inclusive of all Civil Engineers, including the allied profession of Architecture; and, second, that it should be geographically inclusive of all of the United States. At no time does it appear that the founders would have been satisfied with a merely local Society. Is it not quite possible that the quarter of a century of more or less continuous effort on the part

of the little handful of pioneers who labored to found this Society might have borne fruit much more quickly if their vision had been less far-reaching? But if so, it is more than probable that the National Engineering Societies, of which the American Society of Civil Engineers is the oldest, would not have the large membership, influence, and prestige which is theirs to-day.

A diagram showing the growth of membership of the four Founder Societies from their foundation to January 1, 1923, discloses that the growth of the Society from its rebirth in 1867, for twenty years, although slow, had a constant increase. For the following period, to about 1905, the rate of growth was more rapid, and from that date until within the last few years, it was at a still greater rate and compared favorably with that of the other Founder Societies. Quite recently the rate of growth in membership seems to have slackened noticeably. This fact may be accounted for largely by the lack of employment, unsettled conditions, and unrest which have prevailed so generally following the World War. The increase in membership of late appears to be more nearly the normal rate of earlier years, and it is confidently anticipated that the growth of the Society will continue to be at least as satisfactory as it has ever been. There are a large number of professional engineers who are eligible for membership, who, if they availed themselves of the privileges, would, through the activities of the Society, advance the profession and benefit themselves. A high standard for membership qualifications has ever been maintained; this is of the first importance and must in no wise be sacrificed for increase in numbers. The Society's service to the Engineering Profession and as a means of service by the profession to the country are so well established that there can be no question of its permanency. Clearly, what is needed at this time is a continuation of those qualities which hitherto have contributed so largely to the prosperity and usefulness of the Society, namely, an abiding interest and loyalty on the part of the members, an adherence to those policies which have been found by past experience to make for progress and usefulness, and such sane progressiveness and vision as will meet the needs of our day and generation.

Annual Conventions

It has been the practice of the Society to hold an Annual Convention each year during the summer months. This practice was begun in 1869. The notice announcing the time and place of the first Convention, which was held in New York, N. Y., was dated May 10, 1869, and read in part as follows:

"Our Society has of late been impressed with the importance of annually gathering its members in Convention for the interchange of ideas and the discussion of professional subjects, as well as those relating to the extension of its own field of usefulness.

"These objects cannot be attained by means of the twenty-three regular meetings, held during the year, on account of the distant residence of many of its members, but they require the appointment of some day on which all

can meet and strengthen that bond of sympathy which should animate hearts engaged in the furtherance of a common cause.

"It is proposed, therefore, to hold the first of such a series of conventions on the 16th day of June, 1869, commencing at 10 A. M.

"Through the courtesy of the Chamber of Commerce, the meeting will be held in their Assembly Room. It will occupy most of the day, and be followed by a suitable collation.

"The Society relies on the individual efforts of its members for sustaining the interest of the occasion, and desires that you will either come prepared to read a brief professional paper—in case of unavoidable absence will forward such to the Secretary—or else be prepared to make some statement of engineering experience calculated to prove of general interest.

"An early and definite reply on your part is earnestly requested."

In response to this call for the First Annual Convention fifty-five members attended and five formal papers were presented. Of the Second Convention, held the following year, also in New York, N. Y., the report states that the "proceedings were interesting, the spirit of the members excellent, both socially and professionally, but the number present was less than anticipated and hoped for." "This," states Charles Warren Hunt, Secretary Emeritus* of the Society, in his very interesting, but all too brief, "Historical Sketch of the American Society of Civil Engineers," published in 1897, from which much of the above historical data have been taken, "led to the movement to hold future conventions in other localities of the Union, with a view to strengthening the national character of the Society." The Third Convention, in 1871, was again held in New York, N. Y., and the fourth, in June, 1872, was held in the City Council Chamber in Chicago, Ill. The "Historical Sketch", referred to previously, states that it was well attended, twelve papers were presented, and a dinner was served at the Parker House. The Fifth Convention was held in May, 1873, in Louisville, Ky., and the Annual Report refers to it as having been attended by the largest number of civil engineers ever assembled together on this continent; the attendance, from an unofficial source, is given as 79 members.

For some reasons not clear, the Sixth Annual Convention, that of 1874, was again held in New York, N. Y., but was the last held in that city. The first Convention held west of the Mississippi River was at St. Louis, Mo., in 1880, and the convention of the following year, the first outside the United States, was held in Montreal, Que., Canada. In 1886, the Convention reached the Rocky Mountains at Denver, Colo., and the Pacific Coast at San Francisco, Calif., in 1896; the following year, it was held at Quebec, Que., Canada. Only three times since then have Conventions been held outside the United States: In London, England, in 1900, in the City of Mexico, in 1907, and in Ottawa, Ont., Canada, in 1913. There have been no interruptions of these Annual Conventions since their beginning, except in 1917 and 1918, when none was held on account of the World War. Formerly, the places for holding conventions were selected somewhat at haphazard, but lately have been determined by an orderly rotation by Districts.

* Secretary of the Society from 1895 to 1920.

At various times there has been a demand for more gatherings similar to the Annual Conventions. As long ago as 1879, the late Octave Chanute, then a Director and, later, President of the Society, proposed the following:

"*Resolved* that it is the sense of this meeting that the Board of Direction should take immediate steps to provide for holding in various cities, of three general meetings in each year, in addition to the general convention, for purposes of professional intercourse."

This motion was lost. Later, in 1913, in addition to the Annual Convention held in June of that year in Ottawa, Ont., Canada, a general meeting was held in October in New Orleans, La., at which the attendance nearly equalled that of the Convention. Nothing more was done in this matter until 1922, when general meetings were held in April at Dayton, Ohio, and in October at San Francisco, Calif., both of which were as well or better attended than the Annual Convention held at Portsmouth, N. H. This year, in addition to this Convention, a general meeting was held in April in New Orleans, La., and one will be held in October in Richmond and Norfolk, Va. The Board of Direction has decided to continue this policy for another year and plans, as yet tentatively, to hold a general meeting in the spring at some place south of the Ohio River, and in the fall in Detroit, Mich., these meetings to be in addition to the Annual Convention which will be held in June in Pasadena, Calif. Whether these general meetings, held away from Society Headquarters, will become a permanent policy will depend on the interest taken in them by the membership. It would seem that with such a large and widely scattered membership two general meetings and the Annual Convention could very profitably be held annually; they should serve to stimulate the interest of the members in promoting the welfare of the Society, afford greater opportunity for participation in its activities, and help make it more truly a National society. The main purposes of the Convention and general meetings, and as well the Annual Meeting in January, held in New York, N. Y., cannot be better stated now than was done by President Julius Walker Adams at the Annual Convention of 1874, when he said:

"The chief purpose and end of our convention, unlike most gatherings known by this name, is to promote social union among the members of this Society * * * [those absent] will lose the hand-shaking, the personal interchange of the sentiment of fellowship and brotherhood, the knowledge of each other, that basis of true *esprit de corps,* which is the life and soul of a Society like this."

The attendance at, and interest in, the Annual Conventions has not been maintained in keeping with the growth of membership. The Board of Direction and the local committees in charge of planning these features of the Society's activities devote considerable time and thought to them and they are worthy of a more loyal attendance by the members.

Local Sections

The problems confronting a National society are in many respects different from, and at the same time more involved than, those with which

local societies have to contend. Although the prestige of a National society attracts many, the higher dues and qualifications for membership offset this advantage. Only a comparatively small proportion of the members of a National society can be in touch with its activities, and then only at infrequent intervals, whereas the opposite is true with respect to local societies. These handicaps were early recognized, and much thought has been given at various times to devising means to make membership in the National societies not only attractive, but increasingly useful. One such means has been the provision for Local Sections.

The problem of Local Sections is an old one. As far back as 1885, a provision for Local Sections was favorably considered by the Board of Direction in a resolution offered by no less an authority than the late A. M. Wellington, M. Am. Soc. C. E. Repeatedly thereafter, the Board of Direction saw the need of some means through which the interests of the ever-widening geographical distribution of the membership could be placed in closer touch with the Society's affairs, more effectively aid in its up-building, and make it of more value.

In 1905, the Board directed that inquiries be sent out to a large number of members scattered throughout the country to ascertain the feeling with respect to the establishment of Local Sections. At that time, there were only two Local Sections, one at Kansas City, Mo., and the other at San Francisco, Calif. The result of this canvass was far from unanimous in favor of Local Sections, and from some localities there was a decided expression of disapproval. It is interesting to note that the strongest objections came from some cities which now have the strongest Local Sections. The objections were perhaps natural in those cities in which local engineering or technical societies were already functioning, and especially where they included in their membership a larger number of engineers than the local membership of this Society. There is enthusiasm in numbers and more engineers would rally about a large and successful local society than a Local Section of a National society with fewer members. However, with the growth of other National societies came a spirit of rivalry and intensified interest, which, together with the natural increase in local membership and the awakening desire on the part of the members to put more service into and get more benefit out of their Society, brought about a change with respect to Local Sections, making them increasingly popular until, at the present time, there are forty-one, all more or less perfectly functioning. However, the problem of Local Sections is one of complexity and is yet unsolved. The Board is desirous of finding some way in which the Sections can function more effectively and with more co-ordination with the governing body of the Parent Society, so as to make them, in a larger sense, the local representative of the Society and a means of stimulating local interest in it and in all that it represents. In the last analysis this much seems sure—there must be a recognition of a mutuality of interest, helpfulness, and confidence between the Sections and the Parent Society; unless there is loyalty, they both fail. This is a National Society, it has cost much to make it such; to keep it such,

it will be necessary for the Sections to take a broad view of the Society's aims and usefulness and their relation thereto and to guard against an undue emphasis of sectional issues.

It is realized that what has been said here does not answer the question often asked: "What are the purposes and possibilities of Local Sections?" Naturally, the answer will depend largely on local conditions; but is it not fair to assume that generally the purposes and possibilities of the Local Sections of this Society may well be similar to those of a local engineering society, and have, in addition, through the bonds of a strong National society, the advantages of a close association and co-operation with a nation-wide group of men of like mind and aspirations?

Meetings of Board of Direction

The growth of the Society and its nation-wide character have been largely promoted by three important policies adopted in recent years. These policies are: The allowance of mileage to members of the Board of Direction for attendance at Board meetings; the holding of less frequent Board meetings; and by holding Board meetings at intervals away from Society Headquarters.

Payment of mileage for attendance at Board meetings was begun in 1908 and resulted immediately in a larger attendance. Previously, there were repeated instances in which Directors did not attend any of the Board meetings during the entire two or three-year terms of their office. This condition of affairs applied not only to the representatives of districts remote from New York, but was true in lesser degree for many districts not far from Society Headquarters. The mileage allowed at first did not fully cover the necessary expenses incurred in attendance at Board meetings, and it was later increased sufficiently to do so.

Payment of mileage, however, was not of itself sufficient to insure attendance of officers at Board meetings. Prior to 1916 there were ten or more regular Board meetings a year, each meeting generally lasting only one day. Not many officers were able to spare the time for attendance at so many meetings, especially if more than a few hours' travel was necessary to and from Society Headquarters. In 1915, regular Board meetings were reduced to five or six, lasting generally two days; more recently, a change has been made whereby meetings are held quarterly. This materially reduced the demands on the time of officers and resulted in an increased attendance.

Formerly, all Board meetings were held at the Society's Headquarters in New York, except one each year at the Annual Convention. Lately, the Board has met two or more times each year at points other than Society Headquarters. In 1922, Board meetings were held at Dayton, Ohio, Portsmouth, N. H., and San Francisco, Calif. This year, meetings have been held at New Orleans, La., and in this city (Chicago), and one will be held in October in Richmond, Va. All these meetings have been held immediately preceding the Conventions or general meetings of the Society held at the same places. Board meetings held at widely scattered points and at intervals make it easier for members of the Board to be active, stimulate the interest, not only of the officers, but of the membership in the various districts where such

meetings are held, and places the Board in closer touch with the needs and activities of the Society.

Reference to the record of poor attendance at Board meetings during early years should not be interpreted, at least for the most part, as a lack of interest on the part of the officers, but to practical difficulties. Comparatively few men had such command of their time and were financially able to incur the expense of attending ten meetings a year, eight or nine of which were held in New York. Under such conditions, quite naturally, the resident officers dominated the affairs of the Society, as, under similar conditions, would the members in Chicago, Ill., or San Francisco, Calif., Washington, D. C., or Omaha, Nebr. My observation has been, and it is, I think, attested by the record of the Society's growth and prosperity, that during these earlier years, in which the burden of directing the Society's activities were so largely borne by the resident officers, that they served the Society unselfishly, loyally, and efficiently. The Society owes a debt of gratitude to that devoted body of resident members who, through so many years, were mainly responsible for its management.

Technical Divisions

The number of engineering societies is legion. It is difficult to state the exact number as they merge by many gradations from those organized more or less for social purposes, through the various lines of technical activities, to those having high professional qualifications for membership. It has sometimes been said that if this, the oldest Engineering Society, had had a proper vision it would have become the one all-inclusive engineering society of this country. It may well be doubted whether this would have been possible, but, if so, it is more doubtful whether the outcome would have been desirable. The multiplicity of engineering societies has been of great value to the profession in stimulating professional activity and solidarity. Their competition, although expensive, has been helpful and inspiring, and certainly no one organization, or even a few, could have accomplished the work which has resulted through the efforts of the many. Especially is this true in view of the fact that many of the smaller societies, such as the American Railway Engineering Association and the American Society for Testing Materials, are so highly specialized that they cover their particular fields of activity probably much more efficiently than could be done by a large general society. Be this as it may, it would seem certain that the time has now come when there should be little or no need for founding new societies. The recognition now given to Local Sections by the several National societies will tend to check the formation of new societies, and the same end will be effected by the policy recently adopted by the Board of Direction in the provision for Technical Divisions.

Technical Divisions may be formed by twenty or more members of the Society who may be especially interested in some branch of engineering. They are given a large degree of autonomy in the charge of their affairs, may hold their own meetings in charge of their own officers, and conduct their own committee work. There are now organized and more or less per-

fectly functioning, a Highway Engineering Division, an Irrigation Engineering Division, a Power Division and a Sanitary Engineering Division. Other Divisions will doubtless be formed in the near future. A canvass of the membership was recently taken for the purpose of ascertaining the wishes of the members as to additional Divisions. The responses, although not as numerous as expected, were encouraging. A Division of City Planning would seem desirable and is now being organized. City Planning has recently come to the fore as a comparatively new and somewhat neglected field for civil engineers. In this connection, it is interesting to be reminded that, at the first regular meeting of this Society, on January 5, 1853, the topic of the evening was "The Relief of Broadway," and Mr. James Laurie, the first President, presented a plan for the placing of railway tracks above the level of the street. This matter was further discussed at the next meeting, as was also "Other Projects, Including the Widening and Extending of Church and Mercer Streets." With a record like this, the members of this Society should not permit present-day problems of City Planning to pass into the hands of another profession, where it would appear they do not as properly belong.

The formation of these Technical Divisions makes it possible for small groups of members interested in particular subjects to get together more easily and function more efficiently than would be possible by the foundation of a new society intended to cover only a restricted field.

Co-operation

Much has been said of late of co-operation of Engineering Societies as if it was something new. It is not new. There has always been a goodly degree of co-operation; however, the great increase in the number of such societies and the fact that many of them are so highly specialized has seemed to call for an increased co-operation and, at the same time, made it increasingly difficult to bring about.

The membership requirements of some societies stress most strongly technical qualifications, in fact, in some the technical qualifications are highly specialized and are fully met by manufacturers and expert technicians. In others, the outstanding qualifications for membership are those of professional attainments and, in some of these, professional attainments of a highly specialized nature. In some, social or local affiliations are a large factor in membership qualifications. It must be obvious, therefore, that under such widely varying society ideals, co-operation will necessarily be restricted to those matters of common interest. These may be local or National affairs, may be purely technical matters, or be those of a professional character; in each case, the incentive for co-operation will vary. The incentive and opportunity for co-operation depends, therefore, in a very large degree, on a common interest, the purposes and ideals of the several groups and equally so on an approximate equality of ability for the furtherance of that common interest. With such a multiplicity of Engineering Societies as now exist, co-operative efforts, if unduly forced, will naturally tend to a compromise of essentials or to the over-emphasis of many things of minor

importance. In such case, the danger would be to the societies of largest prestige and highest ideals.

This Society has recently, and for the third time, declined to join with certain others in an all-inclusive plan of engineering society co-operative work. There is ample evidence that these decisions have been based on the plan of, and not on the spirit of, co-operation. Clearly this is so, for the whole history of the Society shows, time and time again, a deeply rooted disposition to co-operate fully and freely whenever there has been opportunity to do so effectively. At the present time, there is a very large degree of co-operation between engineering organizations in technical matters. The extensive and excellent work being done by the Engineering Standards Committee, which is sponsored by a number of the engineering societies and participated in by many of their members, is a co-operative effort of high order; the same is equally true of the excellent work of the Division of Engineering of the National Research Council. Much other technical activity is being fostered through the joint agencies of various engineering societies. It makes little difference whether this is accomplished through temporary agencies, such as joint committees, or more permanent agencies. The American Society for Testing Materials and the American Railway Engineering Association may be considered, in view of the fact that many of their members are also members of other less specialized societies, as co-operative organizations by engineers. Effective co-operation calls for united effort and, equally so at other times, that one party shall refrain from duplicating the activities of the other. The setting up of Engineering Foundation for the furtherance of research in engineering and of United Engineering Societies for the management of the joint property interests of the four large National societies, called by these acts the Founder Societies, are other notable instances of co-operation. In other than technical matters, co-operation has not progressed as far, although it is far from being negligible.

In those matters pertaining to the service of the Engineering Profession to the country and those pertaining to the general welfare of the profession, there is room at this time for more concerted activity on the part of engineering organizations. Considering these in their broadest aspects, it would seem as if it was the especial obligation, and as well the privilege, of the large National societies, particularly those in which the professional qualifications for membership are the highest, and which for these reasons have the prestige and wealth of personnel, leadership, and funds beyond those of local or specialized societies, to undertake primarily and largely the burden of representing the Engineering Profession at large. In that case, therefore, the Founder Societies with other National organizations of approximately similar standing and character might profitably set up some agency through which they might co-operate as occasion requires. Such an agency might well meet the following requirements: Its field of activity should be specific. It should have definite responsibility to its sponsors, yet with some freedom of initiation and action. It should be elastic enough to meet varying needs, to act promptly in emergencies, to enlist such aids as might be helpful.

Its vision should be nation wide and its organization such that the influences initiating its action should be no less broad. Its chief function should be largely to bring about concerted action of various organizations as their mutuality of interest and influence might seem necessary, rather than to attempt to speak for them, and it should function so as to leave room for expression of minority opinion or qualified approval where unanimity could not be obtained except as a result of compromise. It should have no incentive to be active solely for the sake of activity. The dangers of a super-organization should be thoroughly guarded against by tying it closely to its sponsors, and it may well be that its organization could be composed of men serving automatically by virtue of their offices in the sponsoring societies. Such an agency, by whatever name it may be called, in addition to being useful in co-operative efforts, would doubtless in large measure promote the welfare of each of the sponsoring societies. Surely of all men engineers should be able to construct an efficient, adaptable, and enduring organization which would foster the spirit of co-operative effort, making it an agency through which the Engineering Profession, in those larger matters in which it is and should be concerned, may be of greater force and effectiveness.

The profession of engineering has certain obligations and responsibilities which its fellow members owe to each other and to the community and the State; these, in most cases, can be best discharged by the individuals through a professional society such as ours. The profession of Civil Engineering has certain rights and privileges which it may properly claim from its fellow members and from the community and the State; these too, in most cases, can be obtained most effectively by the individuals through a society such as this. This Society has in the past been interested in those things which have influenced the standing, the proficiency, and the welfare of the engineer. If its growth and prosperity are to continue, and in even greater degree, then there must follow, especially in these days of society competition, a still greater interest and activity by the Society in all matters that pertain to and concern the welfare of the professional engineer and those matters of public concern in which the engineer can aid in securing a wise solution. The Society can only accomplish its aims and purposes through the efforts of its membership. The need, therefore, is for a continued and increased interest and loyalty on the part of all members.

TENTATIVE SPECIFICATIONS FOR STEEL HIGHWAY BRIDGE SUPERSTRUCTURE

SUBMITTED AS A PROGRESS REPORT OF THE SPECIAL COMMITTEE ON SPECIFICATIONS FOR BRIDGE DESIGN AND CONSTRUCTION

TO BE PRESENTED NOVEMBER 7, 1923

COMMITTEE

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C. R. HARDING, *Secretary.*

June 25, 1923

To the Members
American Society of Civil Engineers:

In submitting for discussion a Tentative Specification for Steel Highway Bridge Superstructure, the Committee hopes to receive a full expression from the Profession, not only as to the general arrangement and scope of the specification, but also as to each specific detail. The Committee acts somewhat as a clearing house for such views and may be guided largely by the expressions of opinion which would be thus obtained.

That the specification has not the unanimous approval of the members of the Committee is well understood, and needs no explanation nor apology. Such is always the case in committee work.

It has been strongly urged by those who have given special attention to highway bridge work, that a specification covering that field, which will be used by manufacturers of limited or recent experience, should enter much more into detail than in the case of railroad bridges which are usually manufactured by firms of long experience and accepted standards. Suggestions might be made, therefore, beyond the clauses as outlined in the specification.

Respectfully submitted,

Henry B. Seaman,
Chairman.

June 25, 1923.

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TENTATIVE SPECIFICATIONS FOR STEEL HIGHWAY BRIDGE SUPERSTRUCTURE

SECTION A.—GENERAL

1.—These specifications cover the design of fixed span bridges and require first-class design, material, and workmanship.

2.—Material.—Bridges shall be made wholly of structural steel except where otherwise specified. Castings shall be of steel, unless cast iron is specifically authorized by the Engineer.

3.—Notice to Engineer.—The Contractor shall give ample notice to the Engineer of the beginning of rolling and of shop work, so that inspectors may be provided. No material shall be rolled, or work done, before the Engineer has been notified where the orders have been placed.

4.—Type of Bridge.—The type of bridge to be used for various span lengths preferably shall be as follows:

Rolled beams up to	40 ft.
Plate girders from	30 to 100 ft.
Riveted half-through trusses from	50 to 100 ft.
Riveted trusses from	90 to 150 ft.
Riveted or pin-connected trusses above	150 ft.

5.—Trusses.—Preference will be given to trusses with single intersecting web members, or other forms of trusses possessing the least ambiguity in computed stresses and the greatest elements of serviceability. Adjustable members in any part of the structure preferably shall be avoided. Members shall be symmetrical about the central planes of the trusses, and all parts shall be designed so that they can be inspected, cleaned, and painted. Through riveted and pin-connected spans will generally have inclined end posts. Half-through trusses shall be of the riveted type.

6.—Spacing of Trusses.—The width between centers of trusses or girders shall be sufficient to give lateral stiffness and to prevent overturning by the specified lateral forces, and in no case shall be less than one-twentieth of the span.

7.—Depth Ratios.—The depth of trusses preferably shall be not less than one-tenth of the span. The depth of plate girders preferably shall be not less than one-twelfth of the span. The depth of rolled beams used as girders preferably shall be not less than one-twentieth of the span. If less depths are used, the section must be increased so that the maximum deflection will not be greater than if these limiting ratios had not been exceeded.

8.—Clearance.—Bridges constructed for highway traffic only shall not encroach on the space indicated by the clearance diagram, Fig. 1. On structures carrying electric railways, the clearance shall be increased to meet the requirements of the case. Clearance from center line of track to the curb on tangent shall not be less than 6 ft. 0 in. and shall be properly increased for curvature and super-elevation of rail.

9.—Traffic Classification of Bridges.—Bridges shall be classified, on the basis of traffic, as follows:

Class *A.*—City bridges or other bridges carrying a highway traffic of exceptionally heavy load units.

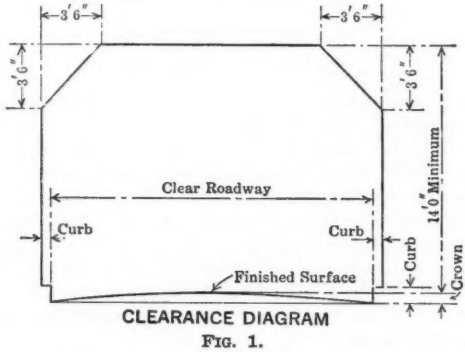
Class *B.*—Bridges on primary roads.

Class *C.*—Bridges on secondary roads.

Class *D.*—Bridges carrying electric railway traffic only, or a combination of electric railway and highway traffic.

10.—Width of Roadway.—The minimum clear width of roadway shall be 9 ft. for each line of traffic, with a minimum of 12 ft. for one line of traffic.

Bridges designed for two lines of traffic preferably shall have a clear width of roadway of not less than 20 ft.



CLEARANCE DIAGRAM

FIG. 1.

11.—Curbs.—The width of curbs shall be not less than 6 in. and preferably shall be not less than 9 in. Their height shall be not less than 8 in.

12.—Dimensions for Calculations.—For the calculation of stresses the length shall be:

For trusses and girders, the distance between centers of bearings;
For floor-beams, the distance between centers of trusses;
For stringers, the distance between centers of floor-beams;

and the depth shall be:

For pin-connected trusses, the distance between centers of pins;
For riveted trusses, the distance between centers of gravity of the chords;
For plate girders, the distance between centers of gravity of the flanges (not to exceed out to out of flange angles) unless section modulus is used.

SECTION 1.—LOADS AND STRESSES

101.—Loads.—Stresses shall be shown separately for the following: Dead load, live load, impact, centrifugal force, and lateral and longitudinal forces. Members shall be proportioned for the combination giving maximum sections, except as otherwise provided.

102.—Dead Load.—In estimating the weight of the structure, for the purpose of computing dead load stresses therein, the following unit weights shall be used:

Steel	490	lb. per cu. ft.
Concrete	150	" " " "
Sand and gravel	120	" " " "
Asphalt-mastic and bituminous macadam	150	" " " "
Granite	170	" " " "
Paving bricks	150	" " " "
Timber	5	" " ft. B. M.

Live Loads

103.—Classification of Highway Live Loads.—For the purpose of design, highway live loads will be divided into four classes, as follows:

1–15
1–20
2–15
2–20

} This classification indicates the number and weight, in tons of 2 000 lb., of loaded trucks on which the live load specification is based.

104.—Selection of Live Loads.—Live loads to be used on the different classes of bridges shall be as given in Table 1.

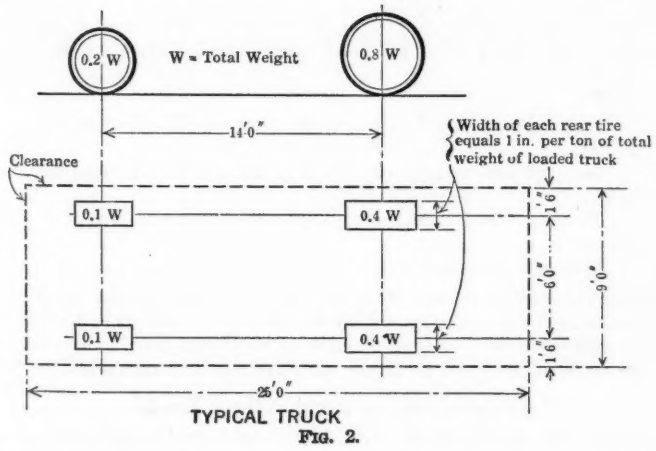
TABLE 1.

Class of bridge.	Live Load:	
	Width of roadway less than 18 ft.	Width of roadway 18 ft. or more.
A	1-20	2-20
B	....	2-15 or 1-20
C	1-15	1-15

Class *D* bridges carrying only electric railways shall be designed for the specified electric railway live loads.

Class *D* bridges carrying both electric railway and highway traffic shall be designed for the highway live loads as herein specified on any portion of the roadway; or the electric railway live loads on the car tracks and the highway live loads on the remaining lines of traffic of the roadway, provided that the clearance is sufficient for at least one line of highway traffic in addition to the railway traffic. For this condition, the clearance line for electric cars shall be taken as 5 ft. 6 in. from center line of track, and 8 ft. shall be considered sufficient for one line of highway traffic.

105.—Concentrated Loads.—Concentrated live loads shall consist of typical trucks having total loaded weights of 15 tons or 20 tons, distributed as shown in Fig. 2.



TYPICAL TRUCK

Fig. 2.

Where highway bridges carry electric traction, the live load shall be as follows:

A train on each track composed of two double-truck cars coupled together. The length of each car shall be taken as 50 ft., with spacing of axles as shown in Fig. 3. The axle loads used shall be suitable multiples of those shown.

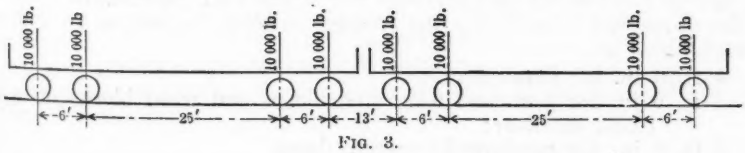


Fig. 3.

106.—Highway Live Loads for Girders and Trusses.—Girders and truss members, except as herein noted, shall be designed for the uniform loads, expressed in pounds per square foot of the roadway between curbs, given in Table 2.

TABLE 2.

Loaded length.	Load.*		
	1-15	1-20 2-15	2-20
50 ft.	100 lb.	130 lb.	180 lb.
100 ft.	80 lb.	90 lb.	120 lb.
200 ft. and more	60 lb.	70 lb.	90 lb.

* Proportionate values for intermediate lengths.

The uniform load used shall correspond to the length of that portion of the span which, when fully loaded, will produce maximum stress in the member under consideration.

When the loaded length is less than 50 ft., girders and truss members shall be designed for the floor live load specified in Article 108. The trucks shall be placed so as to produce the most severe stresses. When two trucks are used, they shall be considered as headed in the same direction. Trucks in tandem need not be considered.

107.—Sidewalk Live Loads.—Sidewalk live loads shall be uniform loads of 80 lb. per sq. ft. for loaded lengths of 50 ft., or less, and 60 lb. per sq. ft. for loaded lengths of 100 ft., or more. For intermediate lengths proportionate loads shall be used. All stringers and brackets of sidewalks shall be designed for not less than 80 lb. per sq. ft.

108.—Floor Live Loads.—All parts of the floor system and all girders and truss members when the loaded length is less than 50 ft., shall be designed for the following loads:

1-15:
One 15-ton truck, or 100 lb. per sq. ft. of roadway.

1-20:
One 20-ton truck, or 130 lb. per sq. ft. of roadway.

2-15:
Two 15-ton trucks.

2-20:
Two 20-ton trucks.

In bridges involving three or more lines of traffic, the floor-beams and floor-beam hangers shall be designed for two trucks assumed to be located in the most unfavorable position, together with a uniform live load of 100 lb. per sq. ft. on the remaining lines of traffic of roadway not occupied by the trucks.

Distribution of Truck Wheel Loads

109.—Shear.—In calculating end shears and end reactions of stringers and floor-beams, no lateral or longitudinal distribution of wheel loads shall be assumed.

110.—Bending Moment in Stringers.—In determining bending moments in stringers, each wheel load shall be assumed to be concentrated at a point.

When the floor system is designed for one truck, each interior stringer shall be proportioned to support that part of one rear-wheel load, or those parts of one front-wheel load and one rear-wheel load, represented by a fraction the numerator of which is the stringer spacing, in feet, and the denominator of which is:

4 ft. 0 in. for plank floors;
5 ft. 0 in. for 4-in. and 6-in. strip floors and wood blocks on a 4-in. plank sub-floor;
6 ft. 0 in. for reinforced concrete floors.

When the floor system is designed for two trucks, each interior stringer shall be proportioned to support that part of one rear-wheel load, or those parts of one front-wheel load and one rear-wheel load, represented by a fraction the numerator of which is the stringer spacing, in feet, and the denominator of which is:

3 ft. 6 in. for plank floors;
4 ft. 0 in. for 4-in. and 6-in. strip floors and wood blocks on a 4-in. plank sub-floor;
4 ft. 6 in. for reinforced concrete floors.

The live load supported by the outside stringers shall be the reaction of a wheel in the most unfavorable position, assuming the flooring to act as a simple beam, but this live load shall in no case be less than would be required for interior stringers under these requirements.

These distribution rules govern only when the stringer spacing is not greater than the denominator which applies to the particular case under consideration. When the stringer spacing is greater than this distance, the stringer loads shall be determined by the reactions of the truck wheels placed in the most unfavorable position, assuming the flooring between stringers to act as simple beams.

The combined load capacity of the stringers in a panel shall be not less than the total live and dead load in the panel.

111.—Bending Moment in Floor-Beams.—In determining bending moments in floor-beams, each wheel load shall be assumed as concentrated at a point.

When stringers are omitted and the floor is supported directly on the floor-beams, the latter shall be proportioned to carry that fraction of one axle load, when the floor system is designed for one truck, or of two axle loads, when the floor system is designed for two trucks, the numerator of which is the floor-beam spacing, in feet, and the denominator of which is:

4 ft. 0 in. for plank floors;
5 ft. 0 in. for 4-in. and 6-in. strip floors and wood blocks on a 4-in. plank sub-floor;
6 ft. 0 in. for reinforced concrete floors.

When the spacing of floor-beams exceeds the denominator given, but is less than the axle spacing (14 ft. 0 in.), each beam shall be proportioned to carry the full axle load or loads.

When the floor-beam spacing exceeds the spacing of axles, the load supported on each floor-beam shall be the maximum reaction due to the axle loads, assuming the flooring between floor-beams to act as a simple beam.

112.—Distribution of Electric Railway Wheel Loads.—Electric railway wheel loads may be assumed to be uniformly distributed longitudinally over a length of 3 ft. 6 in. In the case of ballasted floors, a lateral distribution of 10 ft. for an axle load may be assumed.

113.—Impact.—The dynamic increment of the live load shall be added to the maximum computed live load stresses. For floor-beams and stringers, this increment shall be taken as 30%, and for floor-beam hangers as 60%, of the live load stress. For girders and truss members, the increment shall be determined by the formula:

$$I = S \frac{100}{l + 300},$$

in which,

I = impact or dynamic increment to be added to live load stresses;
S = computed maximum live load stress;
l = loaded length of span, in feet.

Impact shall not be added to stresses produced by longitudinal and lateral or wind forces.

114.—Allowance for Increase of Live Load.—For the calculation of stress reversal or counter stresses, the specified live loads, either uniform or concentrated, shall be increased 100% and, for this load condition, the specified unit stresses shall be increased not more than 50 per cent. The resulting sections shall be not less than would have been required had the allowance for overload not been considered.

115.—Centrifugal Force.—Bridges carrying electric railway traffic on a curve shall be designed to resist a lateral force equal to 10% of the moving railway load without impact allowance. This load shall be assumed to act 4 ft. above the rail.

116.—Lateral Forces.—Spans of 150 ft. and less shall be designed to resist a lateral force of 300 lb. per lin. ft. on the loaded chord and 150 lb. per lin. ft. on the unloaded chord. For spans of more than 150 ft., for each additional 30 ft. of span there shall be added 10 lb. per lin. ft. for the loaded chord and 5 lb. per lin. ft. for the unloaded chord.

All lateral forces are to be considered as moving loads.

117.—Wind Force.—Viaduct towers shall be designed for a horizontal wind force of 50 lb. per sq. ft. on one and one-half times the vertical projection of the structure unloaded.

118.—Longitudinal Force.—Provision shall be made for the starting and stopping of electric railway trains, with a coefficient of friction of 10 per cent.

119.—Temperature.—Provision shall be made for thermal stresses in fixed arch bridges induced by a temperature range of 120° Fahr.

120.—Alternate Stresses.—Members subject to alternate stresses of tension and compression shall be proportioned for the kind of stress requiring the larger section. If the alternate stresses occur in succession during the passage of live load, as in stiff counters, each stress shall be increased by 50% of the smaller.

121.—Combined Stresses.—Members subject to both axial and bending stresses shall be proportioned so that the combined fiber stresses will not exceed the unit stresses given in Article 201. In members continuous over panel points, three-fourths of the bending stress computed as for simple beams shall be added to the axial stress.

122.—For stresses produced by combination of longitudinal or lateral and wind forces with live load, dead load, impact, and centrifugal force, the unit stresses may be increased 25% over those specified in Article 201. When secondary stresses are included the unit stress may be increased 33⅓ per cent. In no case shall the section be less than that required for dead load, live load, impact, and centrifugal force at the unit stresses specified in Article 201, or less than that required if secondary stresses are not considered.

123.—Secondary Stresses.—Secondary stresses shall be avoided where possible in designing and detailing. In ordinary trusses without sub-paneling, secondary stresses due to distortion need not be considered in any member the width of which, measured parallel with the plane of flexure, is less than one-tenth its length. All other secondary stresses shall be considered.

SECTION 2.—UNIT STRESSES

201.—In proportioning the several parts of the structure, the following allowable stresses shall be used:

Allowable Stresses for Structural and Rivet Steel:

	Kips per square inch.
Tension, net section	16.0
Compression (one diameter)	16.0
Compression on columns; gross section:	

$$\frac{16.0}{1 + \frac{l^2}{13\,500\,r^2}}$$

but not to exceed the value for $\frac{l}{r} = 40$,

in which,

l = length of the member, in inches;
r = least radius of gyration of the member, in inches.

	Kips per square inch.
Bending in extreme fibers of rolled shapes, built sections and girders, net section	16.0
Bending in extreme fibers of pins	24.0
Shear in plate-girder and I-beam webs, net section	12.0
Shear in pins and shop-driven rivets	12.0
Shear in power-driven field rivets and turned bolts	10.0
Shear in hand-driven rivets and rough bolts	7.5
Bearing on pins, shop-driven rivets, outstanding legs of stiffener angles, and other steel parts in contact	24.0
Bearing on power-driven field rivets and turned bolts	20.0
Bearing on hand-driven rivets and rough bolts	15.0
Bearing on rollers, pounds per linear inch, d = diameter of roller, in inches	0.6 d
Bearing on countersunk rivets; one-half the depth of countersink shall be omitted in calculating bearing area and, in metal less than $\frac{3}{8}$ in. thick, countersunk rivets shall not be assumed to carry stress.	
Bending in cast iron	3.0
Shear in cast iron	3.0
Bearing on cast iron	10.0

For cast-steel shoes and pedestals, 80% of the allowable unit stress for structural steel will apply.

For members composed of steel of greater strength than structural grade, the allowable stresses may be increased in proportion to the higher yield point of the stronger steel, provided the yield point is not more than 70% of the ultimate strength. In the column formula, the fractional portion of the denominator should be increased in the same ratio.

202.—Allowable Pressure on Masonry.—

	Kips per square inch.
Granite masonry	0.8
Limestone and sandstone (good quality)	0.4
Concrete (1:2:4)	0.6

203.—Compression Flanges of Beams and Girders.—The laterally unsupported length of the compression flanges of beams and girders shall not exceed forty times the flange width. When the unsupported length of flange exceeds twelve times the flange width, the compressive stress, in pounds per square inch, shall not exceed:

$$16\,000 - 150\,\frac{l}{b},$$

in which,

l = length, in inches, of unsupported flange, between lateral connections or knee-braces;
b = flange width, in inches.

Limiting Length of Members

204.—Compression Members.—The ratio of unsupported length to the least radius of gyration shall not exceed 120 for main compression members,

nor 140 for laterals and sway-bracing. In proportioning the top chords of low trusses, the unsupported length shall be assumed as the distance between the rigid verticals.

205.—Tension Members.—For main riveted tension members, the ratio of length to least radius of gyration shall not exceed 200.

Section 3.—Details of Design

301.—Thickness of Metal.—The minimum thickness of structural steel shall be $\frac{1}{4}$ in., except for fillers, railings, and unimportant details. Gussets shall not be less than $\frac{3}{8}$ in. thick. Metal subjected to marked corrosive influence shall be of greater thickness.

302.—Open Details.—Details shall be arranged so as to give free access for inspection and painting. Water-pockets shall be avoided.

303.—Compression Members.—Compression members shall be designed so that the metal shall be concentrated as far as feasible in the webs and flanges, and so that the center of gravity of the section may be as near the center line of the member as practicable.

304.—Rigid Members.—Hip verticals and members performing similar functions, and the two end panels of the bottom chords of pin-connected bridges preferably shall be rigid.

305.—Counters and Adjustable Members.—Rigid counters are preferred. Adjustable counters, when used, shall be designed for an initial stress of 10 000 lb., and shall have open turnbuckles. Only one set of diagonals in any panel shall be adjustable.

306.—Net Sections.—Net sections shall be used in all cases in calculating tension members; and, in deducting rivet holes, they shall be taken as $\frac{1}{8}$ in. larger than the nominal diameter of the rivet. The weakening effect of a staggered rivet shall be allowed for by deducting from the transverse section a strip, w, in width, as given by the formula:

$$w = h - \frac{s^2}{4\,g}$$

in which,

w = width, in inches, of strip to be deducted;
h = diameter of rivet hole, in inches;
s = stagger, or longitudinal spacing of rivet with respect to rivet on last gauge line, in inches;
g = distance between gauge lines, or transverse spacing, in inches.

The effective area of single angles in tension shall be assumed as the net area of the connected leg plus 50% of the gross section of the unconnected leg. The effective area of a double angle tension member shall be assumed as 80% of the net section of the member, unless the end details and connections are such that the individual angles are held against bending in both directions, in which case the full net area may be used.

307.—Pin-connected riveted tension members shall have a net section back of the pin-hole, parallel to the axis of the member, of not less than the required net section of the body of the member, and shall have a net section through the pin-hole at least one-third larger than the required section. Riveted tension members shall be stitch-riveted where necessary to make a compact member.

308.—Maximum Length of Rivet.—The total thickness of plates connected by rivets shall not exceed six times the nominal diameter of the rivet to be used.

309.—Rivet Spacing.—Rivets shall be proportioned by their nominal diameter. They shall not be spaced, center to center, closer than 3 diameters. Maximum pitch in the line of stress for members composed of plates and

shapes shall not exceed sixteen times the thickness of the thinnest material connected, and shall not exceed 6 in. for $\frac{3}{4}$ in. and $\frac{7}{8}$ in., 7 in. for 1 in., 8 in. for $1\frac{1}{8}$ in., and $9\frac{1}{2}$ in. for $1\frac{1}{4}$ in. For angles connected by more than one gauge line, and with rivets staggered, the maximum pitch in each line may be twice the foregoing values. When two or more plates are used in contact, the lines of rivets nearest their edges shall conform to the foregoing, and the rivets on the interior gauge line shall not be farther apart than twenty-four times the thickness of the thinnest material connected in any direction.

In sides of compression members, consisting of only one plate, the pitch of the rivets in the direction transverse to the line of stress shall not be more than thirty times the thickness of the plate.

For cover-plates on compression members, the pitch of the rivets transverse to the line of stress shall not exceed forty-five times the thickness of the plate, provided that, if this pitch is made greater than forty-five times, up to a permissible maximum of fifty times, the excess over forty-five times shall not be considered as effective in resisting stress.

The pitch of rivets at ends of built compression members shall not be more than 4 diameters, for such a distance as will develop the area of the component parts.

Rivets shall not be spaced closer to sheared edges than $1\frac{3}{4}$ diameters, nor to rolled or planed edges, except in flanges of beams and channels, than $1\frac{1}{2}$ diameters, nor farther from the edge than eight times the thickness of the plate.

310.—Size of Rivets.—The diameter of rivets in angles carrying calculated stress shall not exceed one-fourth the width of the leg in which they are driven. In angles the size of which is not so determined, $\frac{5}{8}$-in. rivets may be used in 2-in. legs, $\frac{3}{4}$-in. rivets in $2\frac{1}{2}$-in. legs, and $\frac{7}{8}$-in. rivets in 3-in. legs. In members carrying calculated stress, $\frac{5}{8}$-in. rivets shall not be used, except in $2\frac{1}{2}$-in. legs of angles and in flanges of 6-in. and 7-in. beams and channels.

311.—Use of Bolts.—Unless specifically authorized, bolted connections shall not be used. Bolts, when authorized, shall be unfinished or turned, as may be specified, and shall meet the requirements of Article 416.

312.—Connections and Splices.—No connection, except for lattice-bars and hand-rails, shall contain less than three rivets. All connections and splices, whether in tension or compression, shall be proportioned to develop the full strength of the members, and no allowance shall be made for milled ends of compression members. Continuous compression members in riveted structures, such as chords and trestle-posts, shall have faced ends and full contact bearings at the joints. Splices shall be as near the panel points as practicable and, in general, shall be on that side of the panel point which is subjected to the smaller stress.

313.—Extra Rivets in Packing.—Filler-plates through which stress is transmitted, or splice-plates not in direct contact with the parts they connect, shall be extended for extra riveting.

314.—Latticed Members.—All segments of members in compression, connected by latticing, shall have batten-plates at each end. The thickness of such plates shall not be less than one-fiftieth of the distance between the rivets connecting them to the compression member. In no case shall the length of such batten-plates be less than one and one-quarter times the distance between the connecting member. Where intermediate batten-plates are used, their length shall be at least three-quarters the width of the member. In compression members, the last rivet in the batten-plate shall preferably also pass through the end of the adjacent lattice-bar. The distance between the connections of latticing shall be such that the individual members between them, composing the column, shall be relatively stronger than the column as a whole.

315.—Tension members composed of shapes shall have their separate segments connected by batten-plates, or by batten-plates and lattice-bars.

316.—Lattice-Bars.—Single lattice-bars generally shall be inclined at an angle of 60° with the axis of the member, and double lattice-bars at an angle of 45° and riveted at the intersection. Single lattice-bars shall have a thickness of not less than one-fortieth, and double lattice-bars not less than one-sixtieth, of the distance between rivets connecting them to the compression member.

317.—Latticing of compression members shall be proportioned to resist shearing stress normal to the member not less than that calculated by the formula:

$$R = \frac{Pl}{4\,000\,y}$$

in which,

R = normal shearing stress, in pounds;
P = strength of column as a compression member, in pounds;
l = length of column, in inches;
y = distance from neutral axis to extreme fiber, in inches.

In compression members with cover-plate, the cover-plate will be assumed to take one-half the shear.

The diameter of rivets shall not exceed one-third the width of the bar.

318.—Reinforcing Pin-Holes.—Where necessary, pin-holes shall be reinforced by plates. These plates shall be connected so as to distribute the bearing pressure proportionately over the full cross-section with a minimum of eccentricity. At least one full-width plate on each segment shall extend not less than 6 in. beyond the near edge of the batten-plates.

319.—Forked Ends.—Forked ends of compression members should be avoided. Where forked ends are used, a sufficient number of pin-plates shall be provided to give each jaw the full strength of the compression member. At least one of these plates shall extend to the far edge of the batten-plates, and the others not less than 6 in. beyond the near edge of the batten-plates.

320.—Floor System.—Floor-beams preferably shall be at right angles to the trusses or main girders and shall be rigidly connected thereto. Spans with floor systems preferably shall have end floor-beams. When end floor-beams are not used, the end panel stringers shall be secured in correct position by end struts securely connected to the stringers and to the main girders or trusses. The end panel lateral bracing shall be rigidly attached to the main girders, or trusses, and shall also be attached to the end struts.

Steel stringers preferably shall be riveted between the floor-beams with end connections to the floor-beam webs.

Suitable floor expansion joints shall be provided and attached to the steel-work at the expansion ends of all spans and at other points where they may be required. Apron-plates, when used, shall be designed to bridge the joint properly and to prevent the deposit of roadway débris on the masonry.

321.—Design of Bracing.—Lateral, longitudinal, and transverse bracing shall be composed of rigid members, and shall have riveted connections.

In general, bracing shall consist of a double system of diagonal members with transverse compression members.

All intersections of lateral and sway-bracing shall be riveted.

322.—Lateral Bracing.—Bottom lateral bracing shall be provided in all bridges except I-beam spans, from which it may be omitted. Bottom laterals preferably shall be supported by rigid hangers at the intersections.

Top lateral bracing shall be provided in deck spans and in through spans having sufficient head-room.

Lateral bracing shall have concentric connections to chords at end joints, and preferably throughout.

323.—Portal and Sway-Bracing.—Through truss spans shall have portal bracing, preferably of the two-plane or box type, rigidly connected to the end post and top chord flanges, and constructed as deep as the clearance will allow. The portal bracing shall be designed to take the full end reaction of the top chord lateral system and the end posts shall be designed to transfer this reaction to the truss bearings.

Deck truss spans shall have adequate sway-bracing at the ends and at all intermediate panel points. This bracing shall occupy the full depth of the trusses below the floor system. The bracing shall be proportioned to transfer the end reaction of the top lateral system through the end posts of the truss to the substructure.

Through truss spans shall have sway-bracing at each intermediate panel point if the height of the trusses is such as to permit a depth of 5 ft. or more for the bracing. When the height of the trusses will not permit of such depth, the top lateral struts shall be provided with knee-braces. Top lateral struts shall be at least as deep as the top chord. Sway bracing shall be of ample strength to transfer one-half the wind pressure to the leeward truss.

324.—Cross-Frames.—Deck plate-girder spans shall be provided with cross-frames at each end, proportioned to resist all lateral forces, and shall have intermediate cross-frames at intervals not exceeding 15 ft. These frames shall be connected to the outstanding legs of the stiffener angles and to the girder flanges.

325.—Through Girder Spans.—Through plate-girder spans shall be stiffened against lateral deformations by means of gusset-plates, or knee-braces with solid webs, attached to the stiffener angles and floor-beams. If the unsupported length of the inclined edge of the gusset-plate exceeds sixty times its thickness, the gusset-plate shall have stiffener angles riveted along its edge.

These braces generally shall extend to the clearance line and preferably shall be spaced not farther apart than 15 ft.

326.—Half-Through Truss Spans.—The vertical truss members and the floor-beam connections of half-through truss spans shall be proportioned to resist a lateral force, applied at the top chord panel points of the truss, determined by the following equation:

$$R = 150\ (A + P)$$

in which,

R = lateral force in pounds;
A = area of cross-section of chord, in square inches;
P = panel length, in feet.

Preferably outrigger brackets attached to the vertical posts on the outside of the trusses shall not be used.

327.—Viaduct towers shall be braced both transversely and longitudinally, with a double system of rigid diagonals with riveted connections. Longitudinal and transverse struts shall be placed at caps and bases and at all intermediate panel points. All bracing connections shall be made with gusset-plates. The struts at the base of towers shall be strong enough to slide the movable shoes and provide expansion, with the structure unloaded.

328.—Plate Girders.—Plate girders shall be proportioned by assuming that the flanges are concentrated at their centers of gravity, but in no case beyond the back of the flange angles. One-eighth of the gross section of the web may be considered as flange area, provided the web is properly spliced to transmit its bending moment. For unusual sections, the section modulus shall be used.

329.—The gross section of the compression flange shall not be less than the gross section of the tension flange.

330.—When flange plates are used, at least one on each flange shall extend the full length of the girder. Any additional flange plates shall be of such length as to allow enough rivets to be placed at each end of the plate, beyond the point where it is first theoretically required, to enable the plate to take its proportional part of the total flange stress. At all other points, there shall be enough rivets, connecting the flange plates to the flange angles, to take the part of the flange stress increment carried by the plates.

The upper corner of through plate girders where exposed shall be neatly rounded to a radius consistent with the size of the flange angles and the vertical height of the girder above the roadway. The first flange plate, or a plate of the same width, will be bent around the curve and continued to the bottom of the girder. In a bridge consisting of two or more spans only the corners of the extreme ends need be rounded, unless the spans have girders of varying heights, in which case the higher girders shall have their top flanges neatly curved down at the ends to meet the top corners of the girders in the adjacent spans.

331.—Flange plates which are spliced, shall be properly covered by extra material equal in section to the material spliced. Flange angles shall have angle splices. There shall be a sufficient number of rivets on each side of the splice to transmit the stress value of the parts cut.

332.—The webs of plate girders, wherever cut, shall be fully spliced for shear and bending.

333.—Stiffeners.—Stiffener angles shall be placed at end bearings and at points of concentrated loading; these stiffeners shall not be crimped and shall have outstanding legs proportioned for bearing and extending as nearly as practicable to the edge of the flange angles.

Webs shall be stiffened by angles riveted thereto in pairs on opposite sides, with outstanding legs not exceeding sixteen times their thickness, nor less than 2 in. plus one-thirtieth of the depth of the girder. Intermediate stiffeners shall be placed at intervals not exceeding the depth of the web, nor 6 ft.

334.—If the depth of the web between the flange angles or side-plates is less than sixty times the thickness of the web, intermediate stiffeners may be omitted.

335.—End Bearings.—Expansion ends shall be firmly secured against lifting or lateral movement. Fixed bearings shall be firmly anchored. Spans of less than 70 ft. may be arranged to slide upon steel plates with smooth surfaces. Spans of 70 ft. or more shall be provided with rollers or rockers. Neither rollers nor rockers shall be used for expansion bearings at the top of trestle-posts. Spans of 70 ft. or more shall have hinged or pin-bearings at both ends.

336.—Expansion rollers shall not be less than 4 in. in diameter for spans of 100 ft. or less, and this minimum shall be increased not less than 1 in. for each additional 100 ft. and proportionally for intermediate lengths. They shall be connected by substantial side-bars and shall be effectively guided so as to prevent lateral movement, skewing, or creeping. The rollers and bearing-plates shall be protected from dirt and water as far as possible, and the construction shall be such that water shall not be retained and that the roller nests may be inspected and cleaned with the least difficulty. Pin-bearing expansion rockers preferably shall be of steel.

337.—Pedestals and shoes shall be used and be designed to secure rigidity and stability and to distribute the reaction uniformly over the entire bearing area. They shall be made preferably of cast steel or structural steel. The bottom bearing widths shall not exceed the top bearing widths by more than twice the depth of the pedestal and, when involving pin-bearings, this depth shall be measured from the center of the pin. Where built pedestals and shoes are used, the web-plates and the angles connecting them to the base-plates

shall not be less than $\frac{5}{8}$ in. thick. If the size of the pedestal permits, the webs shall be rigidly connected transversely.

For spans on an inclined grade and without pin or hinged bearings, the sole plates shall be beveled so that the substructure bridge seats will be level.

338.—Anchor-Bolts.—Anchor-bolts for trusses and girders shall not be less than $1\frac{1}{4}$ in. in diameter and shall extend into the masonry not less than 12 in. Washers shall be used under the nut. Anchor-bolts subjected to tension, as in viaduct towers, shall engage 50% more masonry than is required by the uplift.

339.—Eye-Bar Packing.—Eye-bars shall not be packed out of line with the axis of the member more than $\frac{1}{16}$ in. to 1 ft. Members packed on pins shall be held against side movement.

340.—Camber.—For important structures and those designed to carry electric railways, the length of the truss members shall be such that the camber will equal the deflection produced by the dead load plus full live load without impact. Ordinary structures shall be cambered by increasing the length of the top chord approximately $\frac{3}{16}$ in. for each 10 ft. of horizontal projection.

341.—Railings.—Substantial railings shall be provided along each side of the bridge for the protection of traffic. In general, the railings shall be of two classes, *viz.:*

1.—Railings suitable for use on country bridges which are not subject to general pedestrian traffic.

2.—Railings for the protection of pedestrians on bridges of cities and villages.

The top rail shall be located approximately 3 ft. 6 in. above the floor adjacent to the railing and shall be capable of resisting a horizontal transverse force of 100 lb. per lin. ft.

Railings of the first class may consist of not less than two lines of horizontal rails of approved section. Railings of the second class shall consist of an upper and lower rail connected by a suitable web. The clear distance between the floor and the lower rail shall not exceed 6 in.

Preferably the unsupported length of any rail shall not exceed 8 ft., and all connections to the posts, truss members, etc., shall contain not less than two rivets each. Provisions shall be made for movement due to temperature.

Section 4.—Workmanship

401.—General.—All workmanship shall be equal to the best practice in modern bridge shops. The methods used and the character of the work done shall be such that the strength of the various members, as designed, shall be fully realized.

402.—Straightening.—When necessary, the material shall be straightened by methods that will avoid any excessive local internal stresses. Sharp kinks and bends may be cause for rejection.

403.—Shearing Structural Steel.—All shearing shall be neatly done and material exceeding $\frac{3}{4}$ in. in thickness, shall have $\frac{1}{4}$ in. planed from the sheared edges.

404.—Shearing Alloy Steel.—All shearing shall be neatly done and material exceeding $\frac{1}{2}$ in. in thickness, shall have $\frac{1}{4}$ in. planed from the sheared edges.

405.—Rivet Holes.—Material forming parts of a member composed of more than five thicknesses of metal shall be punched, or drilled, with a tool $\frac{3}{16}$ in. smaller than the nominal size of the rivets, and reamed to full size after the parts are assembled. When the holes are made after the parts are assembled, they shall be drilled full size.

406.—Rivet Holes in Structural Steel.—Material forming parts of a member composed of not more than five thicknesses of structural steel may be

punched $\frac{1}{16}$ in. larger than the nominal size of the rivets, whenever the thickness of the metal is equal to or less than $\frac{3}{4}$ in. All metal thicker than $\frac{3}{4}$ in. shall be sub-punched and reamed, or drilled, from the solid.

407.—Rivet Holes in Alloy Steel.—Material $\frac{1}{2}$ in., or less, in thickness forming parts of a member composed of not more than five thicknesses of alloy steel may be punched $\frac{1}{16}$ in. larger than the nominal size of the rivets. Material thicker than $\frac{1}{2}$ in. shall be punched, or drilled, with a tool $\frac{1}{16}$ in. smaller than the nominal size of the rivets, and reamed to full size after the parts are assembled, or drilled from the solid. All metal thicker than the nominal size of the rivets, less $\frac{1}{4}$ in., shall be drilled.

408.—Drifting.—Drifting to enlarge unfair holes will not be allowed.

409.—Riveting.—Rivets shall be heated uniformly to a light cherry red color and shall be driven while hot. The heating of the points of rivets more than the remainder will not be permitted. When ready for driving, they shall be free from slag, scale, and other adhering matter, and, when driven, they shall completely fill the holes. Burned, burred, or otherwise defective rivets shall not be driven.

Loose, burned, badly formed, or otherwise defective rivets shall be cut out. Caulking and re-cupping of rivet heads will not be allowed. In cutting out defective rivets, care shall be taken not to injure the adjacent metal and, if necessary, the rivet shanks shall be removed by drilling.

Shop rivets shall be driven by direct-acting riveters where practicable. The riveting machine shall retain the pressure for a short time after the upsetting is complete.

Pneumatic hammers shall be used for field riveting, except when the use of hand tools is permitted by the Engineer.

410.—Dies.—Punch dies shall not be more than $\frac{3}{32}$ in. larger than the punch.

411.—Web-Plates.—Web-plates of girders which have no cover-plates, shall be flush with the backs of the top flange angles or project above them not more than $\frac{1}{8}$ in.

Web-plates of girders that have cover-plates may be $\frac{1}{2}$ in. less in width than the distance back to back of flange angles. The ends of web-plates at splices shall not be more than $\frac{1}{4}$ in. apart.

412.—Splice Plates and Fillers.—Web-splices, plates, and fillers shall fit within $\frac{1}{8}$ in. of the flange angles.

413.—Web Stiffeners.—Web stiffeners at bearings and points of concentrated loads on the flanges shall be faced and brought to bearing against the flange angles.

414.—Lattice-Bars.—The ends of lattice-bars with single rivets shall be neatly rounded.

415.—Floor-Beams and Stringers.—The main sections of floor-beams and stringers shall be of exact length after riveting, and the end connection angles shall be accurately set to length, and square.

416.—Bolts.—The use of bolts in place of rivets will not be permitted, except for special cases. When bolted connections are authorized, the bolts furnished shall be as specified or directed by the Engineer.

Holes for turned bolts shall be carefully reamed and the bolts turned to a driving fit with the threads entirely outside the holes. The heads and nuts shall be hexagonal. A washer not less than $\frac{1}{4}$ in. thick shall be used under the nut and the thread burred.

Rough bolts shall be standard machine bolts with hexagonal heads and nuts. The use of "button-head" bolts will not be permitted.

417.—Abutting.—Abutting joints shall have a close fit. The abutting surfaces of compression joints which depend on contact bearing, shall be accurately faced.

418.—Eye-Bars.—Eye-bars shall be made by a process that will produce a uniform product. Welds will not be allowed. The form of the heads may be determined by the dies at the works where the eye-bars are made if satisfactory to the Engineer, but the manufacturers shall guarantee the bars to break in the body when tested to rupture. The thickness of the head shall not be more than $\frac{1}{8}$ in. greater than that of the bar, except by mutual agreement in special cases.

419.—Pin Clearance.—The diameters of pin-holes shall not exceed those of the pins by more than $\frac{1}{32}$ in.

420.—Pins and Rollers.—Pins more than 7 in. in diameter shall be forged and annealed. Pins 9 in. or more in diameter shall have a 2-in. longitudinal hole bored through the axis. All pins shall be turned.

421.—Upset Ends.—Bars and rods with screw ends shall be upset to provide a cross-sectional area at the root of the thread which shall exceed the net section of the body of the member by at least 15 per cent.

422.—Steel Castings.—Steel castings shall be free from large and injurious blow-holes and shall be annealed.

423.—Bed-Plates.—Expansion bed-plates shall be planed true and smooth. The finishing cut of the planer tool shall be in the direction of expansion. Cast wall-plates shall be planed on top.

424.—Screw-Threads.—Screw-threads shall be U. S. Standard. The nuts shall fit tight.

425.—Welds.—Welds will be allowed only when authorized by the Engineer and where the unit stress is not more than one-half the ordinary specified working stress.

426.—Pilot Nuts.—Two pilot and two driving nuts shall be furnished for each size of pin.

427.—Field Rivets.—Field rivets shall be furnished in excess of the nominal number required to the amount of 10% plus 10 rivets of each size and length.

428.—Shop Painting.—All surfaces that come in contact or that are closed shall receive one coat of approved paint before being assembled. All steel shall be scraped free of scale and shall receive one coat of approved paint before leaving the shops.

429.—All machined surfaces shall receive a coat of white lead and tallow at the shop.

430.—Facilities for Inspection.—The Inspector shall be allowed access to all necessary parts of the works.

431.—Inspector's Authority.—The Inspector shall have the power to reject materials and workmanship which do not fulfill the requirements of these specifications; but, in case of dispute, the Contractor may appeal to the Engineer, whose decision shall be final.

432.—Rejection.—The acceptance of any material or finished members by the Inspector shall not be a bar to their subsequent rejection, if they are found to be defective.

Rejected material and workmanship shall be replaced promptly or made good by the Contractor.

Section 5.—Full-Size Eye-Bar Tests

501.—Material Tests.—When the acceptance of eye-bars depends on the results of full-size tests, the quality of the material, as proved by the specimen tests, shall be determined by the manufacturer.

502.—Number of Full-Size Tests.—The number and size of the bars to be tested shall be specified by the Engineer before the mill order is placed.

503.—Selection of Eye-Bars.—The test bars shall be the same section as the bars that are to be used in the structure, and of the same length, if within the capacity of the testing machine. Test bars, representing bars too long for the testing machine, shall be selected from the full-length bar material after the

heads on one end have been formed, and shall then be cut and the second head formed to the greatest length that can be tested.

504.—Requirements for Full-Size Tests.—The requirements for full-size eye-bar tests shall be as follows:

	Structural steel annealed eye-bars.
Yield point, in kips per square inch, minimum....	30.0
Ultimate strength, in kips per square inch, minimum	55.0
Elongation percentage, in 18 ft., minimum.....	12

The elongation shall be measured in the body of the bar including the fracture.

505.—Re-Tests.—When a bar fails to meet the requirements, two additional bars of the same size and from the same mill heat may be tested. If two or three bars tested fail, the bars of that size and mill heat shall be rejected.

506.—Payment for Eye-Bars.—Eye-bars thus tested which meet the requirements of these specifications, shall be paid for by the purchaser at the same unit price as for the structure. Bars which fail to meet the requirements of the specifications, and all bars rejected as a result of the tests, shall be at the expense of the Contractor.

Section 6.—Weighing and Shipping

601.—Weight Paid For.—The payment for pound-price contracts shall be based on the weight of metal in the fabricated structure, including field rivets shipped. The weight of erection bolts, field paint, and all boxes, crates, or other containers used for packing, together with sills, struts, and rods used for supporting members during transportation, shall be excluded.

Weights paid for shall be shop scale weights unless otherwise provided. If specified in the contract, or permitted by the Engineer, computed weights as hereinafter provided may be made the basis of payment.

602.—Variation in Weight.—If the weight of any member is more than 2½% less than the computed weight, it may be cause for rejection. This applies to both pound-price and lump-sum contracts.

If the total scale weight of any structure exceeds the computed weight by more than 2%, the weight in excess of 2% above the computed weight shall not be paid for.

603.—Weighing of Members.—Finished work shall be weighed in the presence of the Inspector, if practicable. The Contractor shall supply satisfactory scales and shall perform all work involved in handling and weighing the various parts.

604.—Computed Weight.—The weight of steel shall be assumed at 490 lb. per cu. ft. The weight of cast iron shall be assumed at 450 lb. per cu. ft.

The weights of rolled shapes, and of plates up to and including 36 in. in width, shall be computed on the basis of their nominal weights and dimensions, as shown on the approved shop drawings, deducting for copes, cuts, and open holes.

The weights of plates wider than 36 in. shall be computed on the basis of their dimensions, as shown on the approved shop drawings, deducting for cuts and open holes. To this shall be added one-half the allowed percentages of over-run in weight given in Article 711.

The weight of heads of shop-driven rivets shall be included in the computed weight, assuming the weights to be as follows:

Diameter of rivet, in inches.	Weight, in pounds, for 100 heads.
½	4.5
⅝	8.5
¾	14.5
⅞	21.5
1	31.0

The weight of castings shall be computed from the dimensions shown on the approved shop drawings, with an addition of 10% for fillets and over-run.

To the total computed weight of metal may be added an allowance of 0.4 of 1% for shop paint.

605.—Marking and Shipping.—Members weighing more than 3 tons shall have the weight marked thereon. Bolts and rivets of one length and diameter, and loose nuts or washers of each size, shall be packed separately. Pins, small parts, and small packages of bolts, rivets, washers, and nuts shall be shipped in boxes, crates, kegs, or barrels, but the gross weight of any package shall not exceed 300 lb. A list and description of the contained material shall be plainly marked on the outside of each shipping container.

Anchor-bolts, washers, and other anchorage or grillage materials, shall be shipped to suit the requirements of the masonry construction.

606.—Handling Material.—The loading, transportation, unloading, and storing of structural material shall be conducted so that the metal will be kept clean and free from injury.

Section 7.—Structural Steel for Bridges

These specifications conform to the Standard Specifications for Structural Steel for Bridges of the American Society for Testing Materials.

701.—Steel Castings.—The Standard Specifications for Steel Castings (Serial Designation, A27), adopted by the American Society for Testing Materials, shall govern the purchase of steel castings for bridges. Unless otherwise specified, Class B castings, medium grade, shall be used.

I.—Manufacture

702.—Process.—The steel shall be made by the open-hearth process.

II.—Chemical Properties and Tests

703.—Chemical Composition.—The steel shall conform to the following requirements as to chemical composition:

		Structural steel.	Rivet steel.
Phosphorus...	Acid.....	not over 0.06%	not over 0.04 %
	Basic.....	" " 0.04%	" " 0.04 %
Sulphur.....		" " 0.05%	" " 0.045%

704.—Ladle Analyses.—An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus, and sulphur. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Article 703.

705.—Check Analyses.—Analyses may be made by the purchaser from finished material representing each melt. The phosphorus and sulphur content thus determined shall not exceed that specified in Article 703 by more than 25 per cent.

III.—Physical Properties and Tests

706.—Tension Tests.—

(*a*).—The material shall conform to the requirements as to tensile properties given in Table 3.

(*b*).—In order to meet the required minimum tensile strength of full-size annealed eye-bars, the purchaser may determine the tensile strength to be obtained in specimen tests; the range shall not exceed 14 000 lb. per sq. in., and the maximum shall not exceed 74 000 lb. per sq. in. The material shall

conform to the requirements as to physical properties other than that of tensile strength, specified in Articles 706(*b*), 707(*b*), and 708(*b*).

(*c*).—The yield point shall be determined by the drop of the beam of the testing machine.

TABLE 3.

Properties considered.	Structural steel.	Rivet steel.
Tensile strength, in pounds per square inch	55 000—65 000*	46 000—56 000
Yield point, minimum, per square inch	0.5 tensile strength 1 500 000†	0.5 tensile strength 1 500 000
Elongation in 8 in., minimum percentage	Tensile strength 22	Tensile strength
Elongation in 2 in., " "		

*See Article 706, Paragraph (*b*).
† See Article 707.

707.—Modifications in Elongation.—

(*a*).—For structural steel more than $\frac{3}{4}$ in. in thickness, a deduction from the percentage of elongation in the 8 in. specified in Article 706(*a*), of 0.25% shall be made for each increase of $\frac{1}{32}$ in. of the specified thickness above $\frac{3}{4}$ in., to a minimum of 18 per cent.

(*b*).—For structural steel less than $\frac{5}{16}$ in. in thickness, a deduction from the percentage of elongation in the 8 in. specified in Article 706(*a*), of 1.25% shall be made for each decrease of $\frac{1}{32}$ in. in thickness below $\frac{5}{16}$ in.

708.—Bend Tests.—

(*a*).—The test specimen for plates, shapes, and bars, except as specified in Paragraphs (*b*), (*c*), and (*d*), shall bend cold through 180° without cracking on the outside of the bent portion, as follows: For material $\frac{3}{4}$ in. or less in thickness, flat on itself; for material more than $\frac{3}{4}$ in. to and including $1\frac{1}{4}$ in. in thickness, around a pin the diameter of which is equal to the thickness of the specimen; and for material more than $1\frac{1}{4}$ in. in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen.

(*b*).—The test specimen for eye-bar flats shall bend cold through 180° without cracking on the outside of the bent portion, as follows: For material $\frac{3}{4}$ in. or less in thickness, around a pin the diameter of which is equal to the thickness of the specimen; for material more than $\frac{3}{4}$ in. to and including $1\frac{1}{4}$ in. in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen; and for material more than $1\frac{1}{4}$ in. in thickness, around a pin the diameter of which is equal to three times the thickness of the specimen.

(*c*).—The 1-in. by $\frac{1}{2}$-in. test specimen for pins, rollers, and other bars, when prepared as specified in Article 709, shall bend cold through 180° around a pin 1 in. in diameter, without cracking on the outside of the bent portion.

(*d*).—The test specimen for rivet steel shall bend cold through 180° flat on itself, without cracking on the outside of the bent portion.

709.—Test Specimens.—

(*a*).—Test specimens shall be prepared for testing from the material in its rolled or forged condition, except when it is specified to be annealed, in which case the test specimens shall be prepared from the material as annealed for use, or from a short length of a full section similarly treated.

(*b*).—Test specimens shall be taken longitudinally and, except as specified in Paragraphs (*d*), (*e*), and (*f*), shall be of the full thickness or diameter of the material as rolled.

(*c*).—Test specimens for plates, shapes, and flats may be machined to the form and dimensions shown in Fig. 4, or with both edges parallel; except that bend-test specimens for eye-bar flats may have three rolled sides.

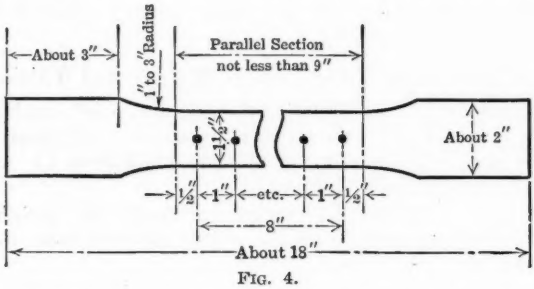


FIG. 4.

(*d*).—Tension-test specimens for plates and eye-bar flats more than 1½ in. in thickness, and bend-test specimens for plates more than 1½ in. in thickness, may be machined to a thickness or diameter of at least ¾ in. for a length of at least 9 in.

(*e*).—Test specimens for bars more than 1½ in. in thickness or diameter may be machined to a thickness or diameter of at least ¾ in. for a length of at least 9 in.; or tension-test specimens may conform to the dimensions shown in Fig. 5, in which case the ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial. Bend-test specimens may be 1 in. by ½ in. in section.

(*f*).—Tension-test specimens for pins and rollers shall conform to the dimensions shown in Fig. 5. In this case, the ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial. Bend-test specimens shall be 1 in. by ½ in. in section.

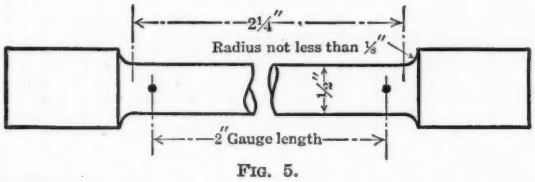


FIG. 5.

(*g*).—The tension-test specimen shown in Fig. 5 and the 1-in. by ½-in. bend-test specimen for pins and rollers shall be taken so that the axis is 1 in. from the surface; and for other bars more than 1½ in. in thickness or diameter, midway between the center and surface.*

(*h*).—The machined sides of rectangular bend-test specimens may have the corners rounded to a radius of not more than $\frac{1}{16}$ in.

(*i*).—Test specimens for rivet bars which have been cold drawn, shall be normalized before testing.

710.—Number of Tests.—

(*a*).—One tension and one bend test shall be made from each melt; except that if material from one melt differs ⅜ in. or more in thickness, one tension and one bend test shall be made from both the thickest and the thinnest material rolled.

(*b*).—If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

* The gauge length, parallel portions, and fillets shall be as shown in Fig. 5, but the ends may be of any form which will fit the holders of the testing machine.

(*c*).—If the percentage of elongation of any tension-test specimen is less than that specified in Article 706(*a*), and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gauge length of a 2-in. specimen, or is outside the middle third of the gauge length of an 8-in. specimen, as indicated by scribe scratches marked on the specimen before testing, a re-test shall be allowed.

IV.—Permissible Variations in Weight and Thickness

711.—The cross-section or weight of each piece of steel shall not vary more than 2.5% from that specified, except in the case of sheared plates which shall be covered by the following permissible variations (1 cu. in. of rolled steel is assumed to weigh 0.2833 lb.):

(*a*).—When ordered to weight per square foot: The weight of each lot* in each shipment shall not vary from the weight ordered more than the amount given in Table 4.

TABLE 4.—PERMISSIBLE VARIATIONS OF PLATES ORDERED TO WEIGHT.*

Ordered weight, in pounds per square foot.	Permissible Variations in Average Weights per Square Foot of Plates for Widths Given, Expressed in Percentages of Ordered Weights:																	
	Under 48 in.		48 to 60 in., excl.		60 to 72 in., excl.		72 to 84 in., excl.		84 to 96 in., excl.		96 to 108 in., excl.		108 to 120 in., excl.		120 to 132 in., excl.		132 in., or over.	
	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under
Under 5	5	3	5.5	3	6	3	7	3	....	....	....	....	....	....	....	....	....	....
5 to 7.5, excl	4.5	3	5	3	5.5	3	6	3	....	....	....	....	....	....	....	....	....	....
7.5 " 10, "	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	....	....	....	....
10 " 12.5, "	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	9	3
12.5 " 15, "	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3
15 " 17.5, "	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3
17.5 " 20, "	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3
20 " 25, "	2	2	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3
25 " 30, "	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	5	3
30 " 40, "	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3
40, or over	2	2	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3

* The weight per square foot of individual plates shall not vary from the ordered weight by more than one and one-third times the amount given in Table 4.

(*b*).—When ordered to thickness: The thickness of each plate shall not vary more than 0.01 in. less than that ordered.

The overweight of each lot† in each shipment shall not exceed the amount given in Table 5.

V.—Finish

712.—The finished material shall be free from injurious defects and shall have a workmanlike finish.

VI.—Marking

713.—The name or brand of the manufacturer and the melt number shall be legibly stamped or rolled on all finished material, except that rivet and

* The term "lot" applied to Table 4 means all the plates of each group width and group weight.

† The term "lot" applied to Table 5 means all the plates of each group width and group thickness.

lattice-bars and other small sections, when loaded for shipment, shall be properly separated and marked for identification. The identification marks shall be legibly stamped on the end of each pin and roller. The melt number shall be legibly marked, by stamping if practicable, on each test specimen.

TABLE 5.—PERMISSIBLE OVERWEIGHTS OF PLATES ORDERED TO THICKNESS.

Ordered thickness, in inches.	PERMISSIBLE EXCESS IN AVERAGE WEIGHTS PER SQUARE FOOT OF PLATES FOR WIDTHS GIVEN, EXPRESSED IN PERCENTAGES OF NOMINAL WEIGHTS:								
	Under 48 in.	48 to 60 in., excl.	60 to 72 in., excl.	72 to 84 in., excl.	84 to 96 in., excl.	96 to 108 in., excl.	108 to 120 in., excl.	120 to 132 in., excl.	132 in. or over.
Under 1/8	9	10	12	14	....	....	....	....	....
1/8 to 3/16 excl.	8	9	10	12	....	....	....	....	....
3/16 " 1/4 "	7	8	9	10	12	....	....	....	....
1/4 " 5/16 "	6	7	8	9	10	12	14	16	19
5/16 " 3/8 "	5	6	7	8	9	10	12	14	17
3/8 " 7/16 "	4.5	5	6	7	8	9	10	12	15
7/16 " 1/2 "	4	4.5	5	6	7	8	9	10	13
1/2 " 5/8 "	3.5	4	4.5	5	6	7	8	9	11
5/8 " 3/4 "	3	3.5	4	4.5	5	6	7	8	9
3/4 " 1 "	2.5	3	3.5	4	4.5	5	6	7	8
1, or over	2.5	2.5	3	3.5	4	4.5	5	6	7

VII.—Inspection and Rejection

714.—Inspection.—The Inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the Inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be conducted so as not to interfere unnecessarily with the operation of the works.

715.—Rejection.—

(*a*).—Unless otherwise specified, any rejection based on tests made in accordance with Article 705 shall be reported within five working days from the receipt of samples.

(*b*).—Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

716.—Rehearing.—Samples tested in accordance with Article 705, which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

SECTION 8.—STRUCTURAL NICKEL STEEL

These specifications conform to the Standard Specifications for Structural Nickel Steel of the American Society for Testing Materials.

I.—Manufacture

801.—Process.—The steel shall be made by the open-hearth process.

802.—Discard.—A sufficient discard shall be made from each ingot intended for eye-bars to secure freedom from injurious piping and undue segregation.

II.—Chemical Properties and Tests

803.—Chemical Composition.—The steel shall conform to the following requirements as to chemical composition:

	Structural steel.	Rivet steel.
Carbon	not over 0.45%	not over 0.30%
Manganese	" " 0.70%	" " 0.60%
Phosphorus, Acid	" " 0.05%	" " 0.04%
Phosphorus, Basic	" " 0.04%	" " 0.03%
Sulphur	" " 0.05%	" " 0.045%
Nickel	not under 3.25%	not under 3.25%

804.—Ladle Analyses.—An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Article 803. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Article 803.

805.—Check Analyses.—Analyses may be made by the purchaser from finished material representing each melt. The chemical composition thus determined shall conform to the requirements specified in Article 803.

III.—Physical Properties and Tests

806.—Tension Tests.—

(*a*).—The material shall conform to the requirements as to tensile properties given in Table 6.

TABLE 6.

Properties considered.	Rivet steel.	Plates, shapes, and bars.	Eye-bar flats and rollers,‡ unannealed.	Eye-bar flats* and plus,‡ annealed.
Tensile strength, in pounds per square inch	70 000-80 000	85 000-100 000	95 000-110 000	90 000-105 000
Yield point, minimum, in pounds per square inch	45 000	50 000	55 000	52 000
Elongation in 8 in., minimum, percentage	1 500 000	1 500 000†	1 500 000†	20
Elongation in 2 in., minimum, percentage	Tensile strength	Tensile strength	Tensile strength	
Reduction of area, minimum, percentage	.....	.....	16	20
	40	25	25	35

* Tests of annealed specimens of eye-bar flats shall be made for information only.
† See Article 807.
‡ Elongation shall be measured in 2 in.

(*b*).—The yield point shall be determined by the drop of the beam of the testing machine.

807.—Modifications in Elongation.—For plates, shapes, and unannealed bars of more than 1 in. in thickness, a deduction from the percentage of elongation specified in Article 806(*a*), of 0.25% shall be made for each increase of $\frac{1}{8}$ in. of the specified thickness above 1 in., to a minimum of 14 per cent.

808.—Character of Fracture.—All broken tension-test specimens shall show either a silky or a very fine granular fracture, of uniform color, and free from coarse crystals.

809.—Bend Tests.—

(*a*).—The test specimen for plates, shapes, and bars shall bend cold through 180° without cracking on the outside of the bent portion, as follows: For material $\frac{3}{4}$ in. or less in thickness, around a pin the diameter of which is equal

to the thickness of the specimen; and for material more than ¾ in. in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen.

(*b*).—The test specimen for pins and rollers shall bend cold through 180° around a pin 1 in. in diameter, without cracking on the outside of the bent portion.

(*c*).—The test specimen for rivet steel shall bend cold through 180°, flat on itself, without cracking on the outside of the bent portion.

810.—Drift Tests.—Punched rivet holes pitched two diameters from a planed edge shall stand drifting until the diameter is enlarged 50%, without cracking the metal.

811.—Test Specimens.—

(*a*).—Test specimens shall be prepared for testing from the material in its rolled or forged condition, except when it is specified to be annealed, in which case, the test specimens shall be prepared from the material as annealed for use, or from a short length of a full section similarly treated.

(*b*).—Test specimens shall be taken longitudinally and, except as specified in Paragraphs (*d*), (*e*), and (*f*), shall be of the full thickness or diameter of material as rolled.

(*c*).—Test specimens for plates, shapes, and flats may be machined to the form and dimensions shown in Fig. 4, or with both edges parallel; except that bend-test specimens for eye-bar flats may have three rolled sides.

(*d*).—Tension-test specimens for plates and eye-bar flats more than 1½ in. in thickness, and bend-test specimens for plates more than 1½ in. in thickness, may be machined to a thickness or diameter of at least ¾ in. for a length of at least 9 in.

(*e*).—Test specimens for bars more than 1½ in. in thickness or diameter may be machined to a thickness or diameter of at least ¾ in. for a length of at least 9 in.; or tension-test specimens may conform to the dimensions shown in Fig. 5, in which case, the ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial. Bend-test specimens may be 1 in. by ½ in. in section.

(*f*).—Tension-test specimens for pins and rollers shall conform to the dimensions shown in Fig. 5. In this case, the ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial. Bend-test specimens shall be 1 in. by ½ in. in section.

(*g*).—The tension-test specimen shown in Fig. 5 and the 1 in. by ½-in. bend-test specimen for pins and rollers shall be taken so that the axis is 1 in. from the surface; and for other bars more than 1½ in. in thickness or diameter, midway between the center and surface.

(*h*).—The machined sides of rectangular bend-test specimens may have the corners rounded to a radius of not more than ⅛ in.

(*i*).—Test specimens for rivet bars which have been cold drawn, shall be normalized before testing.

812.—Number of Tests.—

(*a*).—One tension and one bend test shall be made from each melt; except that if material from one melt differs ¾ in. or more in thickness, one tension and one bend test shall be made from both the thickest and the thinnest material rolled.

(*b*).—If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*).—If the percentage of elongation of any tension-test specimen is less than that specified in Article 806(*a*) and any part of the fracture is more than ¾ in. from the center of the gauge length of a 2-in. specimen, or is outside the middle third of the gauge length of an 8-in. specimen, as indicated by

scribe scratches marked on the specimen before testing, a re-test shall be allowed.

IV.—Permissible Variations in Weight and Thickness

813.—The cross-section or weight of each piece of steel shall not vary more than 2.5% from that specified; except in the case of sheared plates, which shall be covered by the following permissible variations (1 cu. in. of rolled steel is assumed to weigh 0.2833 lb.):

(*a*).—When ordered to weight per square foot: The weight of each lot* in each shipment shall not vary from the weight ordered more than the amount given in Table 4.

(*b*).—When ordered to thickness: The thickness of each plate shall not vary more than 0.01 in. under that ordered.

The overweight of each lot† in each shipment shall not exceed the amount given in Table 5.

V.—Finish

814.—The finished material shall be free from injurious defects and shall have a workmanlike finish.

VI.—Marking

815.—The name or brand of the manufacturer and the melt number shall be legibly stamped or rolled on all finished material, except that rivet and lattice-bars and other small sections, when loaded for shipment, shall be properly separated and marked for identification. The identification marks shall be legibly stamped on the end of each pin and roller. The melt number shall be legibly marked, by stamping if practicable, on each test specimen.

VII.—Inspection and Rejection

816.—Inspection.—The Inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the Inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be conducted so as not to interfere unnecessarily with the operation of the works.

817.—Rejection.—

(*a*).—Unless otherwise specified, any rejection based on tests made in accordance with Article 805 shall be reported within five working days from the receipt of samples.

(*b*).—Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

818.—Rehearing.—Samples tested in accordance with Article 805, which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

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* The term "lot" applied to Table 4 means all the plates of each group width and group weight.

† The term "lot" applied to Table 5 means all the plates of each group width and group thickness.

VIII.—Full-Size Tests

819.—Tests of Eye-Bars.—

(*a*).—Full-size tests of annealed eye-bars shall conform to the following requirements as to tensile properties:

Tensile strength, in pounds per square inch...	85 000—100 000
Yield point, minimum, in pounds per square inch	48 000
Elongation in 18 ft., minimum, percentage....	10
Reduction of area, " "	30

(*b*).—The yield point shall be determined by the halt of the gauge of the testing machine.

RAILROAD TRANSPORTATION AND RAILROAD TERMINALS

A SYMPOSIUM

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SOME PHASES OF PRESENT-DAY RAILROAD TRANSPORTATION

By John W. Kendrick,* M. Am. Soc. C. E.

The railroad system of the United States, as it exists to-day constitutes a monument to the ingenuity of the civil engineer and his confreres, the mechanical and the electrical engineer. The science of transportation has come to embrace everything that is known in all the applied sciences and is not the task or duty of one profession, but of all these professions combined.

Any one who traverses the great transcontinental systems of the United States or the railroads of early construction extending through the Appalachian or other mountain ranges, cannot fail to be impressed by the accomplishment they represent in boldness of conception and wisdom of execution. The engineers were obliged to build for conditions prevailing at that time. No matter how correct their concept of future development of the country might have been, they were limited as to means and were obliged to consider the factor of economic worth of the facility when completed.

With the growth of business, it became necessary for the railroad companies to improve their properties, which required the expenditure of enormous sums. The additional investment justified increases in the rates charged for transportation, which, however, were not forthcoming.

Until about 1890 the operation of railroads was conducted along lines dictated by the comparatively short practical experience that had been gained. The necessity for the adoption of systematic methods was becoming apparent and early in the decade that followed a system of reports was instituted in the Northwest in regard to current operation that, in general, constituted the foundation of the present system of accounting prescribed by the Interstate Commerce Commission. Other similar movements may have been started in other parts of the country at the same time, or earlier, but this particular movement largely affected the railroad systems of the West and Northwest and, later, of the East.

Many of the railroad companies of the West and Northwest doubled their train load during the ten years ended in 1900. Some companies had systematically reduced their grades, and all had improved the quality of their power to some extent. It is fair to state, however, that a large part of the improvement that took place in this period was due to closer and more intelligent supervision.

The records of the Interstate Commerce Commission are available for the history of the growth of the railroad systems and their business from 1890 to 1921, inclusive, although complete statistics are not yet available for 1921.

By comparing the accomplishments of 1920 with those of 1890, one finds that the road mileage of all railroads in the United States increased 60%, miles of all tracks operated, 97%, and operating revenues, 500%, but operating expenses increased 760% and, unfortunately, net operating revenues were 3% less than those of 1890.

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The tons of freight carried 1 mile increased 440% during this period. Passengers carried 1 mile increased 300%, and it should be noted that average revenues per ton-mile increased only 13% and per passenger-mile only 27 per cent.

During the same period the number of employees increased 177%, their total compensation, 800%, and their individual annual compensation, 225 per cent. During the same time, taxes increased 787 per cent.

To a certain extent, the expansion of 1920 was spasmodic, and was followed by a decrease in business in 1921. The expansion, however, commenced again; the magnitude of operations in 1922 was greater than that of 1921, but, whereas the tonnage of 1923 will apparently be greater than ever before, revenues are not increasing in like proportion.

The American people have enjoyed the blessings of cheap and unlimited transportation so long that those born in this era, and many who have survived the period when the railroad was still a struggling enterprise, have come to consider it as a matter of course, and, in fact, have come to look on it as something that was given, if not by the gods, by that part of the public which, having faith in their country and their fellow man, invested their substance in railroad securities.

This country has fallen on evil days in which it has become a matter of interest with some people and an obsession with others, to preach the doctrine that the transportation systems of the country are owned by the representatives of concentrated wealth, and that in the processes of their operation the masses are compelled to pay extortionate prices for transportation for the enrichment of these relatively few and enormously rich people.

In about equal proportions a vast number of men and women of the United States are interested in railroad securities in small lots, not only directly as individual investors, but also severally because of their participation in many great enterprises that are investors in railway securities, notably the companies that insure their lives and property. There are 57 000 000 insurance policies now in force in this country; the savings banks represent the same and millions of other citizens who are investors in railroad securities. The general public is also represented in great educational and charitable institutions which are investors in the securities of the carriers, so that the ownership of the railroads constitutes an important part of practically all that is best and noblest in a great country.

The burden incident to the proper maintenance of the transportation system must be spread over the entire population, because, every one uses or benefits directly or indirectly by the National transportation system.

Rates must be sufficient to maintain the railroads properly. In no way can the people at large escape the cost made necessary by adequate rates. If taxation is resorted to, it will bear on those who have taxable property. Those who have property derive it from industry by the employment of those who may not have property that can be taxed, but those who pay the taxes must collect the money from the general community in the dealings common in all society, therefore, no one can escape.

Average revenues per ton and per passenger-mile have shown little increase during long periods, although there were wide fluctuations in prices of labor, material, and merchandise of all kinds. In the past, the mistake has been made of being more concerned about the cheapness of transportation than about the ability of the railroads to handle promptly all the traffic offered. As a result of the constant pressure for lower rates, railway expansion was arrested at a time when there was a tremendous increase in the capacity for production. Recurrent transportation shortages during the last several years have served to prove that a short-sighted policy is being followed. Good transportation is cheap at any price that is fairly commensurate with the cost of its performance.

For many years practically all railway financing has been accomplished through borrowings, as investors have been reluctant to purchase the stocks of any except the strongest companies and thus assume the greater risk of partnership in the business. Railway capitalization, therefore, has become top-heavy with debt at the expense of the security of railway stocks. What is needed is the bringing of new partners into the business of the financing of railway expansion and improvement through the sale of stock issues.

During the last few years even the strongest companies have had to pay for equipment on a so-called equipment trust plan, which provides for a payment of part of the principal in cash at the outset and the remainder during a term of years. This plan does not enable a railroad to finance such an undertaking on terms as good as it is entitled to receive, for such securities are issued only for a short period and command comparatively high rates of interest.

The course of economic developments during the last twenty years throws much light on the reason the policy of Government regulation that has been followed, has produced the effect it has on the development of the railroads. The Hepburn Act, giving the Interstate Commerce Commission real power to regulate railway rates, went into effect in 1906. At about the same time, the legislatures of numerous States passed laws requiring reductions of freight and passenger rates and created or strengthened railroad or public utility commissions, which themselves soon ordered reductions in rates.

One can now examine the history of prices and wages in this country and determine that at this point great economic changes were beginning which made it the worst time that could have been selected to commence to reduce railway rates. The history of prices shows that it was about this time that, in the prices of commodities, general advances began which were due to world-wide economic conditions and causes. This advancing tendency of prices caused increases in the cost of living, and naturally prompted railway employees to seek advances in their wages. It is a matter of history that the first large advance in railway wages made in years occurred in 1907.

These advances in prices and wages tended to increase the operating expenses of railway companies. In consequence, the companies, in 1910, sought to make a general advance of about 10% in freight rates. This increase was prevented by an Act of Congress which authorized the Inter-

state Commerce Commission to prohibit any advance in rates which it found to be unreasonable, and by a decision of the Commission holding that this proposed advance was unreasonable.

Although the Interstate Commerce Commission could and did prevent a general advance in rates, there was not and could not be legislation to prevent a continuance of the general increase in prices. The result was that in 1914, when the World War began, the average wholesale price of all commodities in the United States was more than 16% higher than in 1906 when effective regulation of railway rates was begun. In 1917, when the United States entered the war, although the average railway freight rate was lower than in 1906, the average wholesale price of all commodities was more than 100% higher. In 1918, it was 128% higher than in 1906; in 1919, it was 146% higher, and, in 1920, almost 183% higher.

This general and almost unprecedented increase in prices caused a corresponding increase in the cost of living, and made necessary further advances in the wages of labor and in other railway operating expenses. Meantime, the railway regulating authorities continued persistently to refuse to make advances in rates which even approached these increases in prices. In 1919, throughout which year the advance in rates made by the Railroad Administration under Government control was in effect, the average freight revenue per ton-mile was only 13½% higher than in 1906, and even the large general advance granted in 1920 made the average revenue per ton-mile less than 70% higher than it was in 1906, although, as has been stated, the average wholesale price of commodities in 1920 was 183% higher than in 1906.

One of the best measures of the prosperity of a railroad or any other business is the operating expenses. If this measure is applied to the results of railroad operation in this country before and since the effective and drastic regulation of rates was adopted, it discloses certain significant facts. During the earlier period of less rigid regulation, say, from 1890 to 1910, there was only one year, 1908—which was a year of depression—that the ratio of operating expenses to operating revenues of the railways exceeded 70 per cent. However, there never has been a year since 1911, when the Interstate Commerce Commission rendered its decision denying the railway companies the first general advance in rates for which they asked, that the ratio of the expenses of railway companies to their earnings has not exceeded 70%, and, in some years, 80 per cent. It is also a notable fact that since 1911 there has been, until recently, a decline in investments in railroad facilities and in the expansion of the capacity of the railroads.

Apparently, the railroad situation in this country has been saved so far by the reduction of ton-mile costs through the untiring and persistent effort to increase the net tons per train-mile, which has offset considerably the enormous increases in expenses that have resulted from other causes heretofore mentioned.

Table 1 shows the average net tons of revenue-freight hauled per freight-train mile and the total freight-train miles for the years named.

In 1921, the net revenue tons per train-mile only decreased to 596 (or 8%) in spite of a falling off of more than 100 000 000 000 ton-miles (or 34%) from the total of the previous year.

TABLE 1.

Year.	Net revenue tons per train-mile.	Total freight-train miles.
1890	175	435 171 000
1900	270	492 568 000
1910	380	671 258 000
1920	647	634 294 000

It should be understood in what follows that the term, "variable cost", means the expense of such functions of operation as vary in accordance with the number of trains run. It is obvious that there are various expenses, such as superintendence and wages of station employees, which are practically fixed regardless of the number of trains run, and there are other expenses that vary in proportion to the increase or decrease of train-miles.

The total ton-miles in 1910, which was about 256 000 000 000 had increased in 1920 to more than 411 000 000 000, or 61 per cent. Attention is called to the fact that, in spite of this increase, there was a decrease of 6% in freight-train miles. This is a wonderful performance, and explains the principal reason for the vitality and strength of the transportation system which has been obliged to endure much. It is a grave question how long the railroad companies can maintain this wonderful financial resiliency.

In arriving at savings on account of the handling of an equal, or greater, tonnage with a reduction in train-miles, the items which vary with fluctuations in train-miles have been selected from the analysis of operating expenses of Class I railways for 1920, published by the Interstate Commerce Commission. The expenses under the various heads were apportioned to freight-train service according to the method prescribed by the Commission. The total of these selected items was found to be $1 404 000 000, and represents 69% of the total charges to the accounts from which these items were drawn, the remainder being chargeable to passenger and allied services and arbitrarily apportioned to such services, and a small amount is unrelated to either freight or passenger services.

The total freight-train mileage in 1920 was 634 294 101, so that the variable cost per freight-train mile was $2.21. In 1910, no attempt was made to allocate operating expenses to freight and passenger operation separately, but the combined cost of these selected items was $628 632 126 and if the same percentage was properly chargeable to freight service in 1910 as in 1920, namely, 69%, the amount of these expenses which was subject to variation, or fluctuation, with increase or decrease in freight-train miles, was $433 756 080, which, divided by 671 257 888, the total freight-train miles in 1910, gives 65 cents as the variable cost of a freight-train mile in that year. Therefore, on this basis, the increase in the variable cost during the ten years from 1910 to 1920, was $1.56, or 240 per cent.

Although some of this increase is undoubtedly due to increased size of locomotives, the larger part is accounted for by the tremendous increases in wage rates of train and enginemen, prices of fuel, together with the increased wages paid the various shop crafts, and other reasons that are well known.

The wages of a standard through freight-train crew, consisting of an engineer, a fireman, a conductor, and two brakemen, increased 124% during the decade under consideration; the price of locomotive coal per ton at the mines increased 187%, and the wages of machinists (taken as typical of the shop crafts) increased 138 per cent. These increased wages and fuel costs are due, of course, to changing economic conditions, but the rates received by the railroad companies for transportation should also vary in accordance with the same changing conditions.

In 1910, the average ton-miles of revenue freight per train-mile on Class I railways was 380, and, in 1920, it was 647, an increase of 267 ton-miles, or 70 per cent. The total freight-train miles in 1920 was 634 294 101, and if the train load had not been increased, that is, if it had remained 380 tons as in 1910, it would have required approximately 444 000 000 more train-miles to have handled the net ton-miles of 1920. Multiplying this by $2.21, the variable cost per freight-train mile in 1920, gives the astonishing total of $981 240 000.

Increase in tractive power of locomotives undoubtedly was a factor in this remarkable result. Although it is impossible to segregate locomotives assigned wholly or principally to road freight service, it is known that the average weight per locomotive owned by Class I railways in 1910 was 73½ tons, whereas, in 1920, the weight was 94 tons, an increase of 28 per cent.

In the speaker's opinion, the increase in train load has been due to increased weight of locomotives, greater capacity of cars, and, to some extent, to reduction of grades and elimination of curvature, but very largely to the supervisory movement for this purpose that has extended throughout the country.

It is evident that a decrease of $1 000 000 000 per year, or even of half that sum, resulting from a period of lean business, which it would be impossible to offset by reduced operating expenses, would bring bankruptcy to many railroad companies. In other words, the railroad companies have an insufficient working balance and are receiving rates that are too low in view of the serious fluctuations in tonnage, regional or general, by which they are constantly threatened.

Increase in train load during the decade ended with 1920 was responsible for a reduction of almost $1 000 000 000 in operating expenses. The amount saved ($981 240 000) is equivalent to a rate of return of more than 5% on the property investment in that year, and also on the tentative valuation ($18 900 000 000) of the Interstate Commerce Commission for rate-making purposes.

There is another point: Railroad companies have invested enormous sums in passenger locomotives, facilities, and equipment. If the subject of variable train-mile costs were considered from a passenger standpoint, as it has been from that of freight movement, there would yet be a further large sum

for which the railroad companies would be entitled to receive credit on account of greater economy due to better devices and the superior quality of supervision with which they have been managed.

The speaker would like to state most definitely and emphatically that the greatest reduction in expenses that has ever been obtained in the operation of the railroads has been through the increase in train tonnage and the diminution in train mileage.

In conclusion, the following is quoted from a pamphlet issued by the Association of Railway Executives, entitled, "Three Years of Railroad Operation Under the Transportation Act":

"The net operating income on Class I roads for the year 1920 was only $17 226 902. The guaranty by the Government for the six months' period, therefore, was the only thing that saved a large number of roads from bankruptcy.

"The statutory return, the net railway operating income, deficit below statutory return, and the rate of return, both on the property investment of the carriers and on the tentative valuation for rate-making purposes by the Commission, are shown in the following table. It is obvious from this table how much Class I roads fell below the realization of a return which was declared by the Commission to be, in its judgment, a fair return. Thus the public's transportation bill, as represented by freight and passenger charges, for the years in question, was reduced substantially two billion dollars at the expense of a fair return to railroad owners on their property devoted to public use.

"NET RESULTS FOR CLASS I RAILWAYS.

Year.	Statutory return.*	Net railway operating income.	Deficit below statutory return.	Rate of Return on:	
				Property investment.	Tentative valuation.
1920.....	$1 134 000 000	$ 17 226 902	$1 116 773 098	0.09%	0.10%†
1921.....	1 134 000 000	600 888 351	533 111 649	3.08%	3.29%
1922.....	1 094 625 000	759 946 000	334 679 000	3.82%	4.09%
Total.....	$3 362 625 000	$1 378 061 253	$1 984 563 747	.....	.....

* "Six per cent. on tentative valuation by Interstate Commerce Commission for rate-making purposes, years 1920 and 1921, and 5¾ per cent, in 1922.

† "Estimated."

The Transportation Act became effective on March 1, 1920. It was the first act of constructive legislation affecting the railroads for many years. It should not be amended or changed in any way to affect adversely its value to the railroads or the public, that is, it should be given a fair trial extending over such periods as may be necessary to point out the defects which it undoubtedly contains. To proceed hurriedly will certainly bring costly errors. It is sincerely to be hoped that a faithful observance of its provisions, both by the Government and the carriers, will prove its worth, but the railroad companies are entitled to receive a fair return on the value of their investment, and that the return has not been fair during the three years that have passed must be conceded by all unprejudiced persons.

TRANSPORTATION AS RELATED TO NATIONAL DEVELOPMENT

By J. G. Sullivan,* M. Am. Soc. C. E.

The world in which we live travels in a definitely fixed path as the result of the balancing of opposing forces. This conflict of opposing forces appears to be a general law of Nature.

The naturalist would doubtless state that the object of our lives is to propagate that the human race may continue to exist. If we take this philosophic view, the speaker thinks we must admit that everything that tends to make life safe, easy, and comfortable, is working in the direction desired.

As an argument in proof of the theory that our object in life is to make a living rather than to create riches, the speaker would call attention to the fact that the estimated wealth of the world for the present population is less than $600 per capita. How is it possible easily to make a comfortable living for all? By increasing the production of the individual. How can this result be obtained? The natural instinct of self-preservation instilled in every man (if not stultified by false doctrines and theories) will result in his making a little more than a living, and this surplus or capital will buy plant and machinery that, in many instances, will increase the production of the individual a thousand-fold.

The most intellectual man, if entirely isolated without tools, would have little advantage over the savage in making a living, but place improved tools and machinery in the hands of the ordinary man, and he will produce sufficient of one or more articles to supply the requirements of hundreds or even thousands. This brings us to the subject of this paper, Transportation.

Without means of transportation to convey economically the products to the consumers, it would be senseless for the miners of a coal district to produce a thousand times more coal than they require for themselves, or for the wheat growers to produce five or six hundred times the quantity they require for themselves. It is not necessary to make out a case for the need of transportation. It is scarcely worth while to discuss transportation by human beings or by animals, it is a matter of ancient history, as far as National development is concerned. There remains to be discussed waterways, railroads (steam and electric), motor cars, and aeroplanes. There is no question but that each has its particular function in the development of a nation, but as far as inland waterways are concerned, it must be borne in mind that they are not as susceptible of general development as the railways; in fact, large areas of the world have been developed by railways, that would have been impossible to develop by waterways, to say nothing of the impracticability on account of the excessive cost of constructing inland waterways as compared with that of building railways. In the speaker's opinion, the inland canal (other than short canals connecting open waterways) is no longer a factor in National

* Cons. Engr., Winnipeg, Man., Canada.

development on the Western Hemisphere. It is realized that there are those who will not agree with this idea.

The speaker was born about sixty years ago in Western New York in the shadow of a high embankment which carried the Erie Canal over a deep ravine. Fifty years ago, he well remembers seeing scores of farmers' teams lined up waiting their turn to unload farm produce into the warehouses on the banks and slips of this canal. Thirty years ago, this business had almost vanished. The farmers in that district were hauling to the freight shed, and the through traffic in grain from Buffalo to New York City was declining. Since that time, the State has spent more than $100 000 000 in the hope of reviving that business, and in the face of all this pampering, one will find men who will state that the railroads killed the canal.

If a corporation can pay for its own thoroughfare and still be able to put out of business the traffic on a free thoroughfare that cost ten to fifteen times as much per mile, the speaker's conclusion is that there is something wrong with that mode of transportation. The motor bus, truck, and car are recent developments. They are performing a very valuable service, but the speaker cannot agree with those who predict that motor-driven vehicles will supplant the street car for short haul or the railroad for freight service of less than 100-mile hauls. The reasons for this opinion are: First, in general, the ratio of dead to live load is in favor of the rail car; second, the necessary tractive force is much in favor of the rail car; and, third, the cost of the roadway is far greater than that for the rail car. Although, at present, the motor trucks have practically free use of these expensive highways, the speaker believes that when the tax-payers realize the damage that heavy trucks cause to pavements and highways, this unfair competition at the expense of the general tax-payer will not be tolerated. It would appear, therefore, that, as far as can be predicted, no form of transportation is likely to compete with rail transportation in future National development.

In Canada and the United States, engineers have witnessed the greatest National development in the history of the world and the greatest and most essential factor in that development has been the railroad. As a reminder, the speaker would call attention to Table 2, which gives a comparison between the railroad mileage and the population of the United States in the past 100 years.

TABLE 2.—Railroad Mileage and Population of the United States

Year.	Railway mileage.	Population.
1830	23	13 000 000
1840	2 818	17 000 000
1850	9 021	23 000 000
1860	30 626	31 000 000
1870	52 922	39 000 000
1880	93 262	50 000 000
1890	166 703	63 000 000
1900	194 262	76 000 000
1910	240 438	92 000 000
1920	252 845	106 000 000

Canadian statistics show a similar growth except for a shorter period. The most striking example of rapid development is in the three prairie Provinces of Western Canada. Forty-five years ago, there were no railways and very little or no export. At present, these Provinces are exporting between 200 000 000 and 300 000 000 bushels of wheat annually, to say nothing of the other grains and farm products. The extent of railway growth and increase in population is given in Table 3.

TABLE 3.—Railway Mileage and Population in Manitoba, Saskatchewan, and Alberta

Year.	Railway mileage.	Population.
1871	None	50 000
1881	Construction started	102 000
1891	3 443 (1894)	232 000
1901	.....	419 000
1906	6 422 (1907)	809 000
1911	8 061	1 323 000
1916	13 581	1 693 000
1921	15 270	1 956 000

A statement has been published* giving the railway mileage of the world in 1917 as 706 730. This means an average increase per year of about 9 000 miles since the beginning of this form of transportation and must have required the expenditure for construction and equipment of not less than $50 000 000 000 or $60 000 000 000, of which a large proportion was financed by private corporations. In Canada, the cash subsidies to railways amounts to $282 000 000, of which the Dominion supplied $220 000 000, the various Provinces about $44 000 000 and the municipalities about $16 000 000. The land grants to railway companies amount to about 46 500 000 acres, of which the Dominion granted 31 500 000 acres and the various Provinces about 15 000 000 acres. Of this land, the Canadian Pacific Railroad Company, the pioneer railroad company in the West, received 25 000 000 acres. The general Subsidy Act that was in force for a number of years prior to 1914, provided a bonus for colonization railways of $3 200 per mile for roads costing less than $15 000 per mile to construct and a further bonus of one-half the cost for roads costing more than $15 000 per mile, up to a point where the total bonus would be $6 400 per mile; that is, a subsidized railway costing $22 400 or more per mile would receive a bonus of $6 400 per mile.

This form of assistance in either cash or land grants resulted in a fairly sound and ample development, but the radical element of the country began a crusade against the alienation of the natural resources or, as they termed it, the people's inheritance. The clamor for railway extensions was general and the politician was in a dilemma; the result was that Canadian legislators pledged the credit of the Government in the form of guaranteed bonds and railway construction boomed, but when these roads failed to make expenses there was no alternative for them except to be taken over by the Government. To-day, we are burdened with an annual deficit of between $60 000 000 and

* *Railway Age*, February 11, 1921.

$80 000 000. In two cases, at least, where Provincial Governments could not induce organized railway companies to build the lines they had projected, they persuaded railway contractors to organize railway companies. In these two cases, the roads are in the hands of the Provincial Governments and are not earning operating expenses, to say nothing of fixed charges which, in one case, amounts to more than $5 000 per mile. These are not pleasant statements, but they are truths known to the public, and the speaker is only repeating them to emphasize the fact that no matter how good the cause or the work, it can be turned into an evil by being carried to extremes.

RAILROADS—THE ARTERIES OF COMMERCE

By J. Rowland Bibbins,* Esq.

Introduction

Transportation is indeed a very human mechanism, patient and long-suffering. Unfortunately, it is likewise subject to fatigue and distress and it slows down when overloaded. The causes of this distress may be profitably examined, together with a perspective of growth and development and the great problem of planning for the future.

Linked with the arterial system are two other very vital members: (1) The heart, or the railroad terminals; and (2), the capillaries, or the underlying distribution system of streets and highways. That they must be considered together is illustrated by the fact that all railroad tonnage, except that which moves carload direct, origin to consumer destination, must pass one or more times over the streets and highways according to the number of fabrications involved.

If the autobiography of an ear of corn was written, the story of transportation would be practically complete—its journeys from producer to consumer would comprise practically every step in collection, manufacture, transit, and delivery. It has been customary to consider only part of the journey—the rail-haul—as the crux of the problem, but this is not sufficient. These other phases will be developed subsequently in the paper.

The Transport System.—At the time of the Civil War the railroads of the United States handled 100 000 000 tons of revenue freight per year, at the end of the century, 1 000 000 000 tons, and to-day, 2 500 000 000 tons. What does it mean to transport 2 500 000 000 tons over 180 miles average haul, also 1 250 000 000 passengers an average of 40 miles? One naturally thinks, first, of 400 000 miles of railroad and terminal tracks, 2 500 000 cars and 66 000 locomotives to haul this traffic. There are, however, more than 15 000 000 gross tons of shipping, big and little, 45 000 miles of electric railways, 12 000 000 motors, and 2 500 000 miles of highway of which 186 000 miles are already designated as the main improved road system of the country. All these agencies form part of the transportation system, and the 2 250 000 tons of parcel post, and 7 600 000 tons of express matter, all of which is largely high-class, expedited freight tonnage should not be neglected. Parcel post, in fact, has become the largest merchandise business in the world and has twice doubled its tonnage within a period of seven years.

Load Characteristics.—One neglected aspect of this great transport plant is that, in no small degree, it is a problem of financing a peak load, just as in the case of a power plant or street railway. These peaks occur every fall season with the movement of commodities and also with every wide fluctuation in the business condition of the country as a whole. Usually, the railroad commodities loading increases between the spring and fall months by about 30%, and then

* Cons. Engr., Washington, D. C.

drops abruptly in midwinter to about 40% below the October peak. The fall peak of the Northwestern District is about 60% above the spring peak.

The reflex of business conditions is shown by the fact that between January and October, 1922, the railway car service ranged from a surplus of nearly 500 000 cars to a shortage of nearly 180 000 cars, representing within 10 months, a swing of more than 25% of the car equipment of the country, or perhaps 75% of the average number of cars loaded weekly throughout the year.

In addition there is the continuing problem of normal growth, and the present situation is worthy of hopeful comment. Business activity is widespread. Revenues and tonnage are moving to new high levels. During the fall of 1922 practically the highest loading and car shortage in railroad history occurred. Instead of a normal traffic drop in the spring of 1923, the railroads recently reached a spring loading equal to that of the maximum fall peak loads of 1922 and 1920, with only a fraction of the car shortage which occurred in the fall of 1922 in handling the same traffic. Here is an evidence of the flexibility of the system when unhampered by labor conditions or feverish business demands of a nation-wide character. Although one may felicitate on present good fortune, this does not necessarily imply a solution for the future, which is one of the main objects of this discussion.

A Long-Haul System.—America is pre-eminently the long-haul country of the world and is vitally dependent on its rail carriers. Compare the 1 000 to 1 500 miles of haul to seaboard from the granger States, with the comparatively short haul of 200 or 300 miles for grain from Argentine, Morocco, Australia, or Southern Russia which sends its grain to sea by waterways, as illustrated by Fig. 1. It is said that a country's prosperity is based on its surplus production, and it is more truth than fiction that what the American farmer receives for his grain is directly dependent on the world price established at the local market at Liverpool less the cost of transportation and not the cost of his production plus transportation. Even the long water-haul which competitors in the various parts of the world have to endure is not as serious as the long land-haul necessary in the United States. Roughly speaking, the cost ratio of water and rail-haul is about 1 to 4.

These factors are what produce trade routes and it is possible to outline quite definitely, various "Economic Divides" running diagonally across the country, tracing the competitive points of movement from the interior to various overseas points by North, South, Gulf and Pacific ports. On this theory of the country as a great economic drainage basin, the great arteries of commerce—the railroads—must provide the logical channels of movement dictated by economic needs and conditions throughout the world, as well as here. The fact that the preponderant movement is now east and west across the Appalachian Range, simply reflects a natural development under the urge of European demand. The South Seas, however, are rapidly drawing from the North, often resulting in the famous "trade triangle" so much prized as an antidote for empty European bottoms homeward bound. In fact, the great development of Southern and Western ports, points to a gradual shifting of the

"trade vector" southward. The railroads will have to meet this situation as it develops.

Rate Control.—This great railroad network of about 265 000 miles of line is clearly the mainstay of our National life, and the rate system, the most sensitive part of the mechanism, whether right or wrong, has resulted in the establishment of thousands of communities where forests and deserts formerly existed. It is evident that a considerable distortion of these complex rate relationships must inevitably force a gradual re-adjustment of the location of industries, due to the relative importance of the factors of labor, raw materials, and transpor-

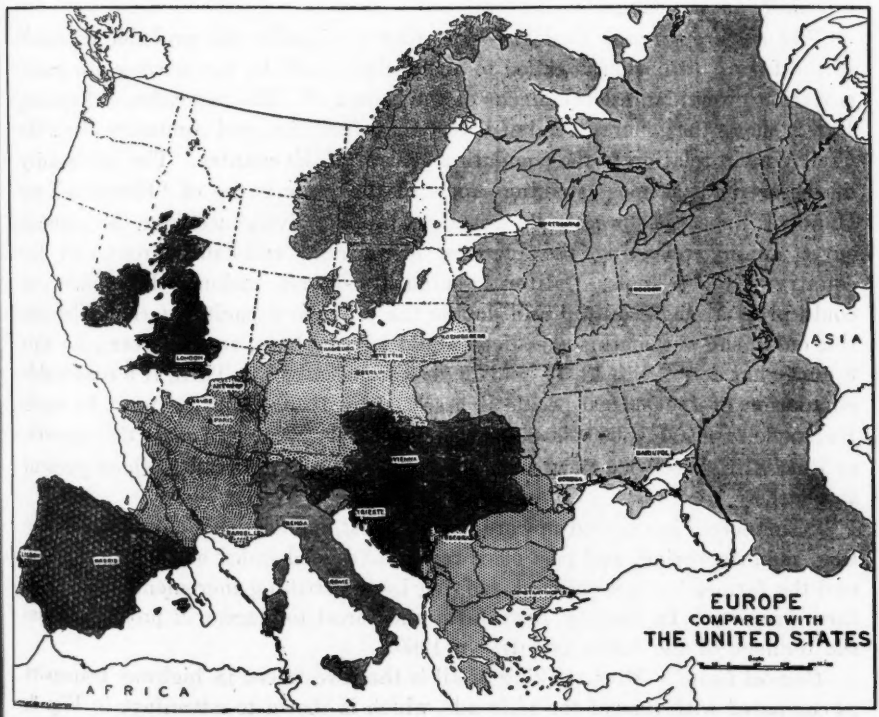

FIG. 1.*—OUTLETS TO THE SEA, UNITED STATES AND EUROPE.

tation. For instance, doubling rates to seaboard would mean that the great grain-producing interior would suddenly be thrust twice as far into the interior as compared with seaboard production. In fact, it is conceivable that greatly distorted long-haul rates might result in the forcing of all industries to the congested seaboard.

Decentralization.—This is exactly the opposite to a policy which will bring about a homogeneous nation with a distribution of population as nearly uniform as topography and climate will permit. The railroads and the rate structure are the most important elements in this National control of settlement.

* Copyrighted, S. A. Thompson, Secy., National Rivers and Harbors Congress, Washington, D. C.

There is a great need of decentralization both in population and industry, not only country-wide, but also in the cities themselves. Although the growing percentage of city population may be due simply to accretion rather than to migration from the country districts, it is clear that it has brought about problems of city congestion which may soon require drastic treatment. Highway development is undoubtedly aiding in this decentralization, but the railroads are the main avenues through which this desired redistribution will be brought about. It is not inconceivable that such further decentralization may gradually help to cure the labor troubles with which the country is afflicted, especially in the congested centers.

The Future a Large Problem.—In order to visualize the probable demands of the future, attention is called to an original study by the speaker, on transportation growth and development of the country.* The logarithmic diagram, Fig. 2, shows the general trend of investment, facilities, and commerce since the Civil War in relation to the population growth of the country. The uniformity of these trends is most striking—most of the basic curve of "Revenue-Tons Handled" appears as practically a straight line, its divergence from the tonnage curve simply reflecting the increase of average rail-haul throughout the country—Oregon apples, California spinach, Colorado melons. If, to-day, one could press a magic button and double the tonnage capacity of the railroads, this curve shows that this expedient would last, perhaps, only 15 years, for this tonnage has doubled in 12, 14, and 18 years, successively. Then, if a reasonable population of 130 000 000 people is assumed by 1940, provision must be made for traffic of nearly 4 000 000 000 revenue tons per year. To meet this growth, at least $10 000 000 000 new capital must be found, if invested along present standards.

"Commerce" has moved upward quite as fast, namely, coal and steel production, manufacturing, and post-office receipts (a good index of small business), and the farmer has not suffered, judging by the striking increment in value of farm property. In fact, by 1940, farm and forest tonnage will probably equal the tonnage of the entire country in 1900.

Capital Input.—Most striking of all is the investment in highway transport as compared with that of the railroads, which is shown to advantage in Fig. 3, representing capital input in 10-year periods. Thus, for the decade ending with 1910, highway transport commanded about one-third of the capital put into railroads; in the decade ending with 1920, it commanded four times as much capital as railroads, that is, approximately, $16 000 000 000, out of a total for all transportation of $23 000 000 000, against $4 000 000 000 for railroads.

These facts indeed challenge attention. Although the gross railroad investment per ton handled has reduced from about $17 in 1880, to about $8 to-day, little reduction has been made within the last twenty years, in spite of greatly increased traffic and efficiency—a fact that seems to indicate that the majority of the new capital has gone into expensive terminals, which is also indicated by an analysis of the track-mileage additions through the years.

* Study made while Mgr., Dept. of Transportation and Communication, United States Chamber of Commerce, Washington, D. C.

Status To-Day.—The investment situation to-day is shown in a general way in Fig. 4, representing an engineering estimate approximating the pre-war level of values without deduction for accrued depreciation or such violent deple-

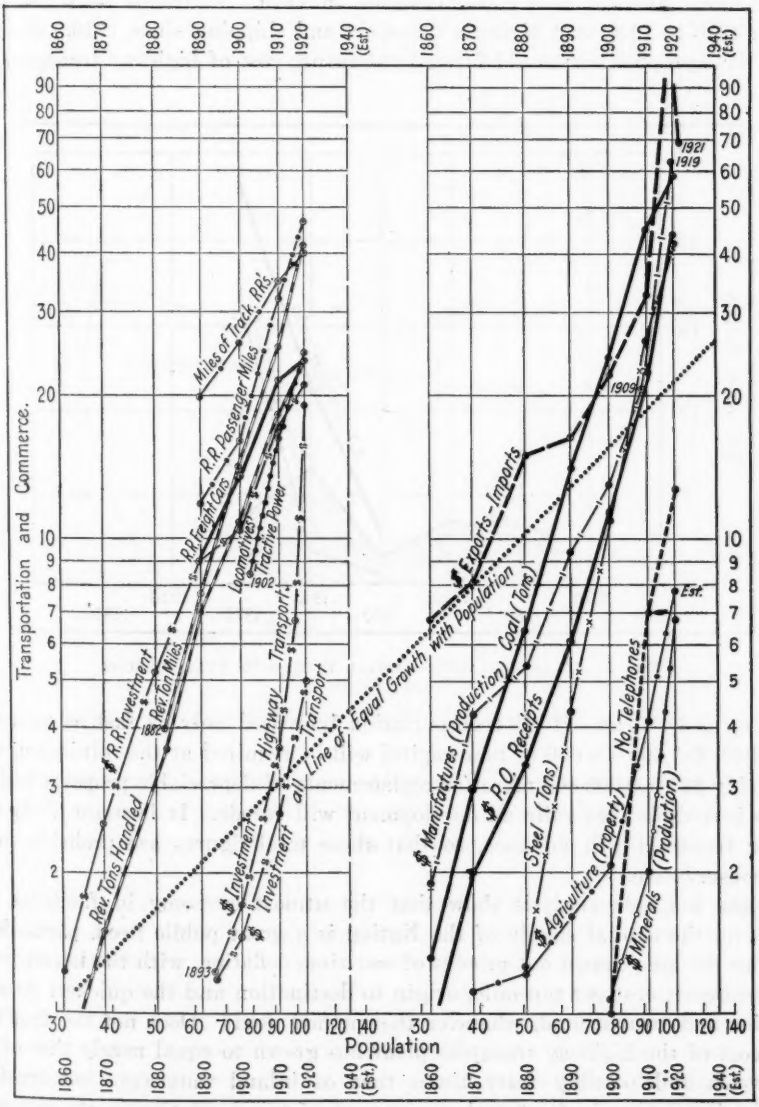

FIG. 2.—GROWTH OF TRANSPORTATION AND COMMERCE WITH POPULATION.

tion in values, as in shipping, brought about by the absence of a "going market". This estimate shows that transportation is the second industry in the United States, costing, approximately, $50 000 000 000 to build, which is about twice

the National debt. It is next to agriculture, $80 000 000 000, and exceeds manufacturing, $45 000 000 000. In general terms, the cost ratio is approximately 2 : 2 : 1 for railroads, highway transport, and other agencies, respectively. This great transport plant has grown from $14 000 000 000 in 1900, to $26 000 000 000 in 1910, and $50 000 000 000 in 1920. Railroads held the stage from 1900 to 1910, and highway transport and shipping since 1910. It would be a wise prophet who could foretell the future cost of highway transport.

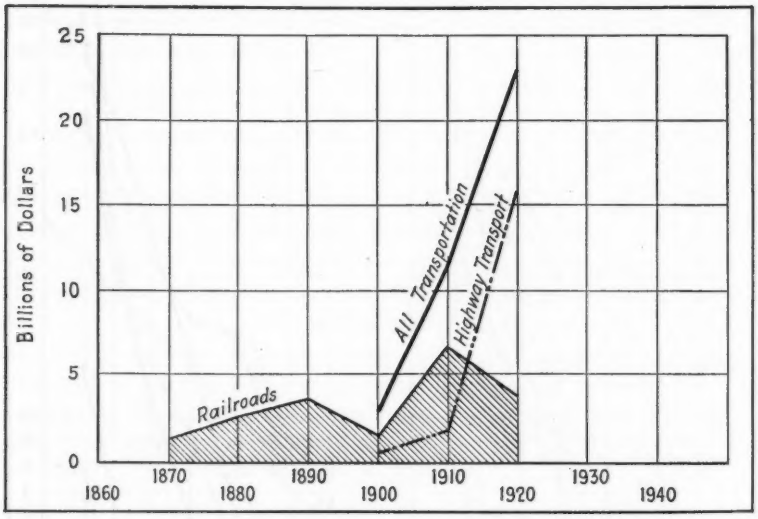

FIG. 3.—TRANSPORTATION CAPITAL INPUT—10 YEAR PERIODS.

Status by 1940.—If all transportation increased only as fast as railroads, by 1940, $25,000 000 000 of new capital will be required at the minimum, with probably $25 000 000 000 more for replacements of depreciable property retired. It is incredible that railroad development will recede. It is more likely that other transport will advance, so that these total figures are probably much too conservative.

Does not this analysis show that the utmost economy in facilities and draft on the capital supply of the Nation is a great public need, particularly during the long drawn out process of war-time deflation, with the lowest possible transport cost per ton-mile, origin to destination and the quickest possible service and turn-around, whatever the method used? Does not the fact that the cost of the highway transport plant has grown to equal nearly that of the railroads and possibly forty times that of inland waterways construction, emphasize the need of a broader treatment of transportation in the future so as to include not only the "arteries" but also the "heart" and the "capillary system"? Some evidence of possibilities in this regard is offered by the American Railroad Association's betterment program for 1923, which encourages, as its major feature, higher efficiency in railroad operation by increasing the daily

mileage of the average freight car, the average load per car handled, and decreasing the number of bad-order cars laid up. This very moderate program of betterment could probably add more than 20% to the existing service capacity of the rail system without additional equipment or capital investment; but no such program can be a complete success without the proper co-operation of

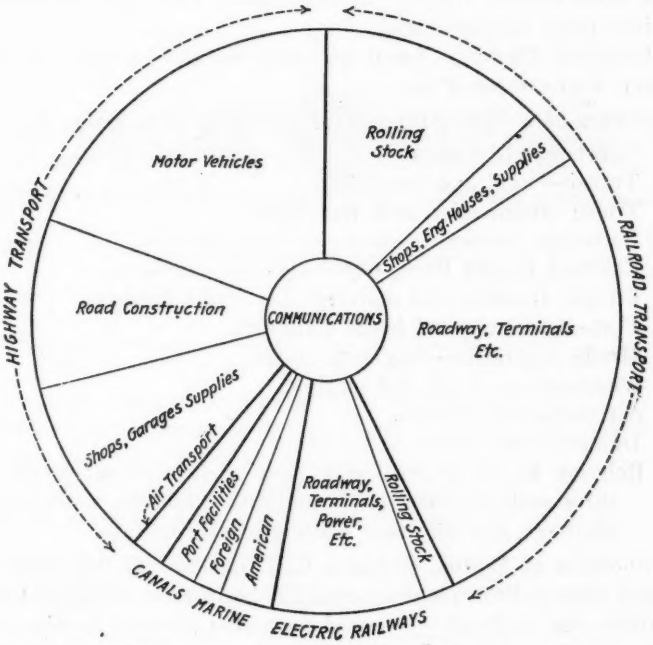

FIG. 4.—COST DISTRIBUTION—$50 000 000 000 TRANSPORT PLANT.

the public and its delivery agencies which, in the last analysis, simply recognize the fact that transportation is, after all, a complete movement from origin to destination and that terminal delivery as well as the rail-hauls are involved.

The fact is that the traffic of the Nation has grown in geometric ratio to the population, while facilities in freight-houses, team-tracks, wharves, transit lines, and particularly streets and roadways in the large centers, have increased, if at all, only in arithmetic ratio. Thus, railroad tonnage has increased nearly as the cube, and ton-mileage nearly as the fourth power, of the population. Terminal tonnage is probably increasing as the cube of the population, especially in view of the growing proportion of city population to the total in the country. Motors, however, are increasing far beyond the fourth power of the population and city motors probably as fast if not faster. Nevertheless, in the majority of cities, practically nothing is being done to survey and develop the capacity of the street system for handling this enormous flood of passenger and freight traffic—for transfer and city destination. Instead, building heights

are being forced upward, which only intensifies the problem. In many cities, local transportation is becoming a crucial problem, due largely to the interference of these conflicting sources of traffic.

Metropolitan Transportation Planning.—It is becoming apparent that cities and railroad companies have many problems in common which would seem to gravitate to two immediate questions of National importance:

(1).—A Metropolitan District Transportation Plan for the larger industrial districts, ports and gateways.

(2).—Terminal Planning based on such surveys, which will merge in to the larger Metropolitan Plan.

The elements of a Metropolitan Transportation Plan embrace:

(*a*) Streets and highways.
(*b*) Transit—local and interurban.
(*c*) Traffic organization and regulation.
(*d*) Railroads—passenger entrances and terminals.
(*e*) Railroad freight lines, terminals and clearing.
(*f*) Freight transfer and delivery, city and suburban.
(*g*) Port—terminals and barge terminals.
(*h*) Grade separation—way and traffic.
(*i*) Warehousing—local and marine.
(*j*) Air ports and airways.
(*k*) Industrial expansion and zoning.
(*l*) Relation to the general city plan—governing all other city features such as parks, public buildings, schools, water supply, and drainage, and all other matters of city welfare.

The authorities of Boston, Chicago, Los Angeles, and Baltimore are considering such metropolitan planning, and in the interest of the major carriers of the country—the railroads—it would seem that immediate steps should be taken to develop in a broader way such an important phase of metropolitan plan as terminals.

Various Government agencies are at work on the vastly important subjects of consolidations, labor, rates, valuation, etc. Assuming, of course, that a fair solution will ultimately be found, it is perhaps no exaggeration to state that the larger question of future transport will undoubtedly focus in the terminals and that some form of physical, financial, or operating unification will be evolved to ensure command of the transport situation; that is that terminal evolution in the gateways and large centers offers the greatest opportunity of increased capacity and minimum investment in which ship, barge, motor, and trolley, as well as rail, must each play its part. Here, in a large degree, lie the controllable wastes in transportation, both off and on rail, and it is evident that the maximum efficiency of the arteries of commerce—the rail lines—can never be secured until the heart of the system—the terminals and their distributing agencies—are able to function as they should.

Terminal Planning.—A basic survey is of the greatest value in terminal planning to show the actual traffic movement and the relative placement and use of facilities, for cities vary widely in traffic characteristics. Recent ter-

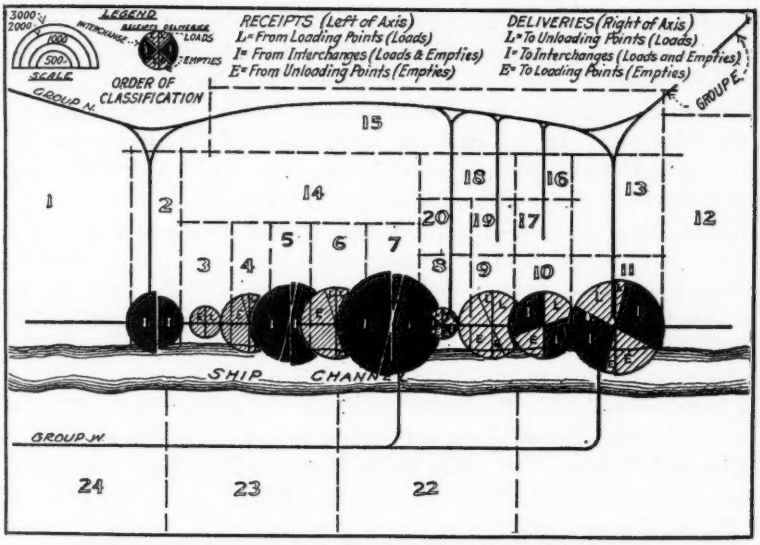
LEGEND
SCALE
ORDER OF CLASSIFICATION
RECEIPTS (Left of Axis)
L= From Loading Points (Loads)
I= From Interchanges (Loads & Empties)
E= From Unloading Points (Empties)
DELIVERIES (Right of Axis)
L= To Unloading Points (Loads)
I= To Interchanges (Loads and Empties)
E= To Loading Points (Empties)
GROUP N.
GROUP E.
GROUP W.
SHIP CHANNEL
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
22 23 24

FIG. 5.—BELT RAILROAD TRAFFIC SURVEY—ACTUAL WORK.

minal surveys showed that in Chicago* more than half the car movement is through interchange, whereas in New York City, it is only about 17%,† excluding the marine traffic, and the same in New Orleans.‡ Such a survey reveals immediate probabilities in the better use of facilities. Thus, Figs. 5 and 6 compare the actual and the useful work of a switching belt line in a large

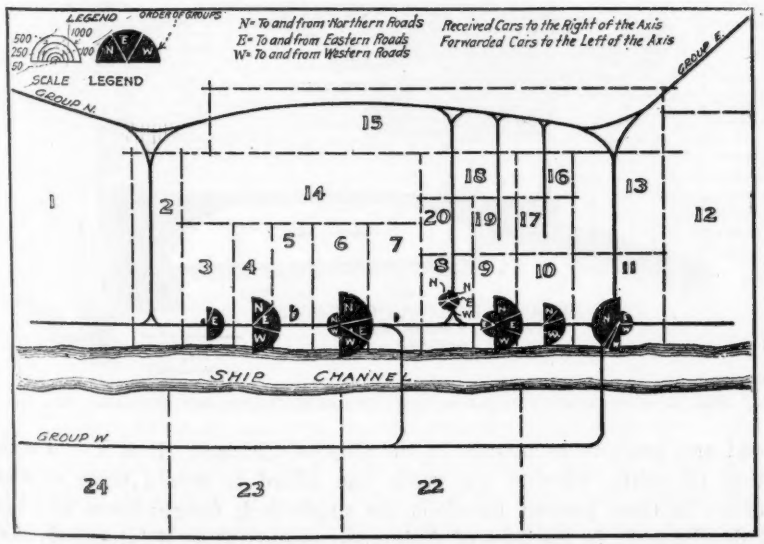
LEGEND
ORDER OF GROUPS
SCALE
LEGEND
N= To and from Northern Roads
E= To and from Eastern Roads
W= To and from Western Roads
Received Cars to the Right of the Axis
Forwarded Cars to the Left of the Axis
GROUP N.
GROUP E.
GROUP W.
SHIP CHANNEL
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
22 23 24

FIG. 6.—BELT RAILROAD TRAFFIC SURVEY—USEFUL WORK.

* Bion J. Arnold report, Chicago terminals.
† Port of New York Authority report.
‡ Board of Advisory Engineers report.

port-terminal city which is not equipped with clearing or storage yards and the necessary facilities to handle interchange outside the congested centers. In obtaining these results, the speaker, as Engineer in Charge, conducted a complete origin-destination count of all freight traffic of the terminal district for a typical month. In this case, the largest part of the interchange is done in the congested marine zone, whereas it should be done outside that zone, at strategic points of contact with connecting rail systems.

Terminal Land Values.—Such a survey should also comprehend a study of land values with respect to proper use and possible re-location. These values, which offer one of the greatest undeveloped resources of the railroads to-day, have grown by accretion of neighborhood land values until their values for commercial purposes are far above those for railroad purposes. About half the entire railroad investment of the country is in other than main-line track, that is largely terminals. Generally speaking, the entire terminal system of the country is developed on a one-story plan, except in notable cases like New York City and Chicago. In many cities, these terminal lands are strangling the future expansion of the business districts. Fig. 7* shows the comparative

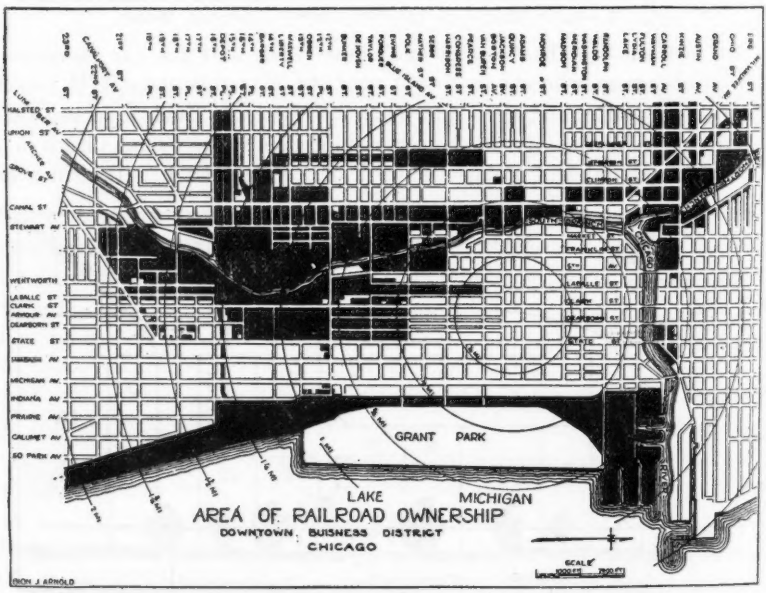

FIG. 7.—COMPARATIVE RAILROAD AND BUSINESS OCCUPANCY, CHICAGO, ILL.

railroad and business occupancy in the City of Chicago. It is now a serious question of policy whether the roads can afford to retain these expensive properties in their present locations for single-deck freight-house and team-track development in the face of their great rental value, if intensively developed by the use of the "air rights" and through the use of the motor truck for collection and delivery. One railroad company in Chicago, found that it could

* Bion J. Arnold report.

afford to recede its in-lying terminals 2 or 3 miles south, using motors for hauling all city freight, and still make a profit from the operation, using the present terminals for office, warehouse, and loft building development at an additional profit from rentals. Thus, it may be that motorizing terminal service may become an interim measure which will largely increase terminal efficiency and release these tremendous land values for further profitable development, more in consonance with the needs of the city and districts wherein they are located.

The development studies in New York City and Chicago are cases in point, and there would seem to be much opportunity for progress in New England, particularly in Boston, Mass. Fig. 8 shows in a striking way the situation in Chicago where land values in the Loop District are greatly exaggerated, due to the iron band of rail operations surrounding the Loop. It is obvious that Chicago cannot expand until some re-organization of terminal facilities takes place, especially toward the south and probably with a recession of the freight operations to a point where this tonnage debouched on the public streets will not be so concentrated as at present. When the "valleys" are filled up, the enormous capital resources in these reclaimed lands will be realized as in the Park Avenue development in New York City.

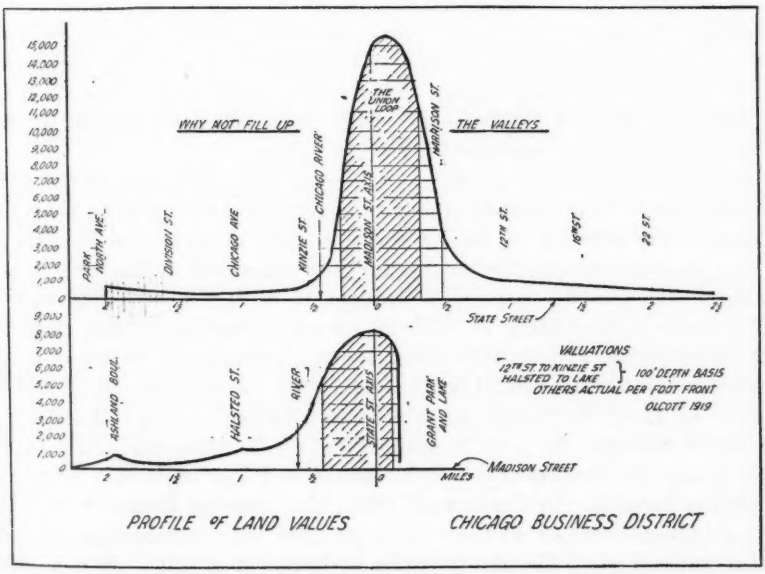

FIG. 8.—PROFILE OF LAND VALUES, MAIN BUSINESS AXES OF CHICAGO, ILL.

Motorways and Rapid Transit.—It is appropriate here to direct attention to the future strategy of more effective use of the immensely valuable railroad rights of way entering city terminal districts. In many cases these rights of way are well located for heavy motorways alongside to handle the city freight from the receded freight terminals and also for rapid transit lines, from the development of which the railroads may better participate in commuter

business and at the same time save the community duplicate investments in parallel rights of way for subways and elevated lines which can only be procured to-day at a tremendous cost for land condemnation and damages. By such a joint plan it seems clear that very large savings in both capital and operating expense could be made for the benefit of all, and more important still, such accommodation of rapid transit facilities would relieve the railroad from the heavy capital burden of maintaining monumental passenger stations for a type of business which should be carried on rapid-transit rails with their stations distributed through, instead of concentrated at one point, in the business district.

Accounting.—It is a curious fact that the accounting system of the Interstate Commerce Commission does not provide a set-up for the specific determination of terminal costs. Some of the larger roads have made these determinations independently and the results are striking. Recently, one road in the Chicago gateway found that it cost nearly 40% more than the per diem received to switch a foreign car over its lines, and various estimates are on record in which the terminal costs were equal to the cost of a 400 or even a 1 000-mile haul. On the average, it is probably not far from true that the terminal cost loading on the country's freight is more than the cost of rail-haul for the average distance hauled (about 180 miles), and with a further refinement of terminal accounting this equivalent would probably be greater. In the motor industries, this is one of the great issues to-day, and adequate cost accounting has barely begun, owing to the laxity and unfamiliarity with cost factors of those in the business. This alone will determine in the future the range of economic possibilities for the motor.

Street and Highway Capacity.—Another issue is clear, that if the railroad terminals are to be relieved by motorizing, serious study must be given to the problem of the capacity of streets and highways to serve them. This problem has received practically no thought or concerted action and only the growing congestion of to-day has brought it to the front. Passenger and freight traffic is interfering on business streets to such an extent, as to choke business properties and actually bring about a recession in values of business proper, which otherwise should be on the increase. Just before the World War, a survey of L. C. L. freight movement in Chicago* showed that 60% was transferred through the city to connecting roads, more than half of it by trucks using the down-town business streets and less than half by trap-cars and freight tunnels. In Cincinnati, Ohio, this trap-car freight is now being handled between various stations by motor cars with interchangeable bodies. All this traffic is going through the business streets of the city. Here is another problem which must be solved in a reasonable way for the larger benefit of the entire community. It points clearly to the need of trucking by pass streets and detour routes, avoiding the central districts and yet giving the motor freight a chance to reach all parts of the city with reasonable speed. In Chicago, the first enterprise of this kind, known as the South Water Street Improvement, has been started. This will provide a wide double-deck detour

* Bion J. Arnold report.

thoroughfare around the Loop District, next to the river bank, with high-speed vehicles above and trucks below. In addition, it will provide a very large automobile storage capacity at the boundaries of the Loop District for all-day storage of business men's cars, thus entirely avoiding the terminal congestion.

The Water and Road Arteries.—There should be no misapprehension in the minds of any one analyzing National transportation as to the functions that waterways and highways should play in the whole scheme. Both are distinctly supplemental carriers, one long-haul and the other short-haul. In both cases, future development must envisage the integration of these systems with the great railroad network, in order to fulfill the proper demand of the American public for the best, quickest, and cheapest over-all transportation, origin to destination, regardless of the method. America has only one great long-haul internal waterway—the Mississippi River and its tributaries, with its new canal connection with the Great Lakes. Such a waterway naturally constitutes a great intercepting trunk line for through movement in large units between strategic rail-connecting points.

It is difficult to understand how such a waterway system can ever become of maximum utility without joint rates and through routes with the railroad system, due to the comparatively limited littoral which can be served by the waterways. In the interest of National efficiency, it would seem that all the people should have the advantage of water transport where they can use it to advantage. Under such circumstances, it is logic and justice that the economies of water transport which will develop automatically with increased traffic should be reflected back into the railroad system in some equitable manner through rates, so that both rail and water-haul may participate in these economies. A system of contract-agency operation equitable to all parties could be devised to fulfill this condition.

Outside the Mississippi System, the Warrior is the longest navigable river not even excluding the Hudson. This means that the majority of the inland rivers will be confined to local, or comparatively short-haul, tonnage which must stop at the seaboard until the intra-coastal canal system is developed as a water belt line interconnecting all these river estuaries with one another and with all seaboard ports and cities. As this whole waterway system matures and tonnage develops, water transport may reveal unlooked-for economies, especially if it is linked up with railroad hauls where economic conditions warrant.

The cost of waterway development will probably never mount into the large figures needed for rails and motor transport. It is demonstrable to-day that the total cost of developing the Lower Mississippi (about $100 000 000, less than half of which went into new construction) has been paid back many times by accretion in values and production within the territory now released from flood and destruction. This is conservation more than navigation. Who are the beneficiaries? Obviously, not only land-owners, but also the cities, highways and railways, State and Nation. Again, the total cost of developing and maintaining the inland waterways of the country, excluding harbors and

estuaries, since the beginning of the Nation's history is probably not more than one-half of what the country spends in one year on public roads and will spend on railroads for the next year. There is, therefore, much idle talk about the "pork-barrel". When a fair operating plan is worked out by contract agency or otherwise, by which these waterways can be properly integrated with the railroad system, as they must be for achieving their larger usefulness, the opposition will probably disappear over night.

The Highway System.—The highway system is in much the same category. Highways are the capillaries of the railroad system, but only since the World War has attention been directed to the fact that the great problem of collection and distribution of rail freight rests largely on the highways. In fact, it is demonstrable that it costs the country as much to haul freight to and from the railroad as to haul it on the rails, and in the end the highways must transport the greater part. Motor competition with the railroad sinks into insignificance beside the larger problem of efficient terminal collection and delivery. The economic relation of long and short-haul costs, road *versus* rail, is rapidly being developed by the Connecticut road tests and other studies and will soon be reasonably well known.

A better organization of the off-rail movement to and from railroads will soon be needed in order to release the full line capacity of the latter and enable the terminals to operate in movement rather than storage. This will provide a quicker turn-around, not only for cars, but also for ships and motors themselves. It will provide the much needed "vacuum pump" to clear the terminals more promptly.

It is a curious fact that the Transportation Act of 1920 does not visualize in any degree this function of highway transport as a railroad auxiliary in through transport, origin to destination. This places the burden of working out a practicable plan of co-ordination on the carriers themselves, and there are evidences to-day of a sincere desire on the part of both motor and rail executives to unite on a better organization of this off-rail movement.

Cost and Benefit.—Another great need to-day is a better understanding of the economic relation of cost and benefit in these great public improvements, both waterways and highways. This lies at the very basis of all public aid projects. The three most important elements in this problem of allocation are: (1) The general public at large; (2) property owners; and (3) the user or carrier. The curve of rise in value of farm property since the Civil War, especially since 1900, as shown on Fig. 2, indicates clearly that some effective agency has been at work. The same rise has taken place in city property where great public improvements are involved. Although local district assessment has long been used for city improvement, tunnels, street widenings, etc., only a blanket assessment or general spread of assessment has been used in the country. Conservation has increased the value of flood lands from practically nothing to perhaps the highest value of farm lands in the State. Highway construction has given to farm lands values corresponding with suburban property levels.

There is disposition on the part of some of the carriers to advocate placing on the waterway and highway user, the total costs of both development and maintenance, which, of course, must be reflected in the operating costs and rates of these new agencies. This does not seem to be either a constructive or a far-sighted policy, which is quite evident from the very reasonable assumption that, ultimately, existing carriers may be enabled to use these waterways and highways for their own traffic through some form of contract agency or even direct operation under proper regulation.

The real question then is to ascertain a fair economic division of costs and benefits for the good of the whole country. In the case of highways particularly, it is probable that highway transport will soon come to a basis of true cost of service just as in public utility properties to-day, and that in the long run a pay-as-you-use policy will bring economic stability to the new transport agency which has shown such remarkable virility in its development.

FEDERAL VALUATION OF RAILROADS

By Edwin F. Wendt,* M. Am. Soc. C. E.

Introduction

The purpose of this paper is to show the relation of valuation to the railroad problem. The passage of the Transportation Act, 1920, made fundamental changes in the relations of the Interstate Commerce Commission and the railroads, and the discussion of the question now under consideration is one of considerable importance, both to the carriers and the public.

The Transportation Act

The Supreme Court of the United States, speaking through Chief Justice Taft, on February 27, 1922, in Railroad Commission of Wisconsin *vs.* Chicago, Burlington and Quincy Railroad Company, No. 206, October Term, 1921, made the following significant statement:

"The Interstate Commerce Act of 1887 was enacted by Congress to prevent interstate railroad carriers from charging unreasonable rates and from unjustly discriminating between persons and localities. The railroads availed themselves of the weakness and cumbrous machinery of the original law to defeat its purpose, and this led to various amendments culminating in the amending Act of 1910 in which the authority of the Commission in dealing with the carriers was made summary and effectively complete. Whatever the causes, the fact was that the carrying capacity of the railroads did not thereafter develop proportionately with the growth of the country, and it became difficult for them to secure additional investment of capital on feasible terms. When the extraordinary demand for transportation arose in 1917, the Congress and the President concluded to take over all the railroads into the management of the Federal Government, and by joint use of facilities, which the Anti-Trust Law was thought to forbid under private management and by use of Government credit, to increase their effectiveness. This was done by appropriate legislation and executive action under the war power. From January 1, 1918, until March 1, 1920, when the Transportation Act went into effect, the common carriers by steam railroad of the country were operated by the Federal Government. Due to the rapid rise in the prices of material and labor in 1918 and 1919, the expense of their operation had enormously increased by the time it was proposed to return the railroads to their owners. The owners insisted that their properties could not be turned back to them by the Government for useful operation without provision to aid them to meet a situation in which they were likely to face a demoralizing lack of credit and income. Congress acquiesced in this view. The Transportation Act of 1920 was the result. It was adopted after elaborate investigations by the Interstate Commerce Committees of the two Houses. * * *

"* * * The latter, the most novel and most important feature of the Act, requires the Commission so to prescribe rates as to enable the carriers as a whole or in groups selected by the Commission, to earn an aggregate net railway operating income equal to a fair return on the aggregate value of the railway property used in transportation. * * *

"The Act sought to avoid excessive incomes accruing, under the operation of Section 15*a*, to the carriers better circumstanced by using the excess for loans to the others and for other purposes. The Act further put under the

* Cons. Engr., Washington, D. C.

control of the Interstate Commerce Commission, 1st, the issuing of future railroad securities by the interstate carriers; 2nd, the regulation of their car supply and distribution and the joint use of terminals; and, 3rd, their construction of new lines, and their abandonment of old lines. * * *

"It is manifest from this very condensed recital that the Act made a new departure. Theretofore the control which Congress through the Interstate Commerce Commission exercised was primarily for the purpose of preventing injustice by unreasonable or discriminatory rates against persons and localities, and the only provisions of the law that inured to the benefit of the carriers were the requirement that the rates should be reasonable in the sense of furnishing an adequate compensation for the particular service rendered and the abolition of rebates. The new measure imposed an affirmative duty on the Interstate Commerce Commission to fix rates and to take other important steps to maintain an adequate railway service for the people of the United States. This is expressly declared in Section 15*a* to be one of the purposes of the bill."

Paragraph (3) of Section 15*a* requires:

"The Commission shall from time to time determine and make public what percentage of such aggregate property value constitutes a fair return thereon, and such percentage shall be uniform for all rate groups or territories which may be designated by the Commission. In making such determination it shall give due consideration, among other things, to the transportation needs of the country, and the necessity (under honest, efficient and economical management of existing transportation facilities) of enlarging such facilities in order to provide the people of the United States with adequate transportation: * * *"

The Supreme Court, speaking through Justice L. D. Brandeis, February 19, 1923, in The New England Divisions Case, No. 646, October Term, 1922, made the further significant statement:

"Transportation Act, 1920, introduced into the federal legislation a new railroad policy. Theretofore, the effort of Congress had been directed mainly to the prevention of abuses; particularly, those arising from excessive or discriminatory rates. The 1920 Act sought to ensure, also, adequate transportation service. That such was its purpose, Congress did not leave to inference. The new purpose was expressed in unequivocal language. And to attain it, new rights, new obligations, new machinery, were created. The new provisions took a wide range. Prominent among them are those specially designed to secure a fair return on capital devoted to the transportation service. Upon the Commission, new powers were conferred and new duties were imposed.

"The credit of the carriers, as a whole, had been seriously impaired. To preserve for the nation substantially the whole transportation service was deemed important. * * * It was necessary to avoid unduly burdensome rate increases and yet secure revenues adequate to satisfy the needs of the weak carriers. To accomplish this two new devices were adopted; the group system of rate making and the division of joint rates in the public interest. Through the former, weak roads were to be helped by recapture from prosperous competitors of surplus revenues. Through the latter, the weak were to be helped by preventing needed revenue from passing to prosperous connections. Thus, by marshalling the revenues, partly through capital account, it was planned to distribute augmented earnings, largely in proportion to the carrier's needs. This, it was hoped, would enable the whole transportation system to be maintained, without raising unduly any rate on any line. The provision concerning divisions was, therefore, an integral part of the machinery for distributing the funds expected to be raised by the new rate-fixing sections. It was, indeed, indispensable."

Key to the Problem

The key to the future success of Federal regulation of railroads will depend in large measure on the valuation of the properties engaged in the service of the public. The Valuation Act, Section 19*a* of the Interstate Commerce Act, was approved March 1, 1913. The Act provides: "That the Commission shall, as hereinafter provided, investigate, ascertain, and report the value of all the property owned or used by every common carrier subject to the provisions of this Act."

The Engineering Board

Within the sixty days prescribed by the Act, the Commission promptly organized a Bureau of Valuation in charge of a Director. The Engineering Board was appointed on May 1, 1913. The Board, which consisted of five engineers all of whom were members of the Society, was charged with the responsibility of the engineering work, subject to the approval of the Director and the Commission. The United States was divided into five Districts which were designated as Eastern, Central, Southern, Western, Pacific. Each District included approximately 50 000 miles of railroads. The Board held 283 meetings, the first on May 6, 1913, and the last on September 22, 1920. The general meetings of the Board were held at Washington, D. C. Five complete technical staffs were organized by the Engineering Board and located at the various headquarters of the Districts—the Eastern at Washington, D. C., the Central at Chicago, Ill., the Southern at Chattanooga, Tenn., the Western at Kansas City, Mo., and the Pacific at San Francisco, Calif. These technical staffs were substantially the same in their organization, and consisted of: Civil Engineer in charge of roadway and track; Bridge Engineer in charge of structures; Architect in charge of buildings; Mechanical Engineer in charge of locomotives, cars and shop machinery; Electrical Engineer in charge of power plants and electric traction; Signal Engineer in charge of signals and interlockers; and Telegraph and Telephone Engineer in charge of telegraph and telephone work. There was also a complete office organization for the assembling of all the data into final engineering reports.

The Engineering Board during its existence of eight and one-half years from May 1, 1913, to October 31, 1921, supervised the work of inventorying the entire 250 000 miles of railroads in the United States. The work was done in great detail in accordance with the provision of the Act which required that:

"The Commission shall make an inventory which shall list the property of every common carrier subject to the provision of this Act in detail, and show the value thereof as hereinafter provided, and shall classify the physical property, as nearly as practicable, in conformity with the Classification of Expenditures for Road and Equipment, as prescribed by the Interstate Commerce Commission."

The length of each and every road, including the various main tracks, spurs, and sidings, was actually measured by engineering corps fully equipped for this work. All excavations and embankments were cross-sectioned and computed. The bridges, buildings, signals, water stations, fuel stations, shops,

roundhouses, turntables, cars, locomotives, shop machinery, signals, interlockers, telegraphs, telephones, gas plants, power plants, and all appliances of every kind and description were inspected, measured, enumerated, and computed in accordance with the standard practices of the Engineering Profession. The field work of making the inventory measurements, and the office work in connection with the computations, collections, and assembly of the quantities of the different classes of property, was done with such care and thoroughness that both the carriers and the public have been well satisfied with the results of the work.

The work was done under detailed printed instructions governing the Roadway, Bridge, Building, Signal, Mechanical, Electrical, and Telegraph Departments. These instructions were disseminated over all parts of the country, and copies are to be found in the offices of the State Railroad Commissions as well as in the offices of the railroads. Great care was exercised in the preparation of these instructions which regulated the work of the field engineers. The maximum force of engineers, accountants, and land appraisers engaged at one time on this work was 1 500, and the Engineering Profession may well feel proud of the accomplishment of the great task of collecting the fundamental data required by the Valuation Act.

Prices as of June 30, 1914

Having completed the field work of collecting the essential engineering data, the Commission proceeded to price the engineering works on the basis of prices as of June 30, 1914. This basis was stated in detail on page 136 of the Texas Midland Decision:

"After careful consideration it was felt by the Commission that it would be unwise and unsafe to depend chiefly upon the opinion of experts; that the only certain foundation upon which to rest was the experience of the past. Unit prices, for example, are being applied as of June 30, 1914. The attempt is not to determine the exact price of a particular article on that date, for that price may have been abnormally high or low, but rather to ascertain what may be termed a normal price. For this purpose it was thought that the range of prices over a period of 5 years previous, and in some cases 10 years, should be consulted. The Commission therefore passed an order, known as Order No. 14, requiring carriers to state the prices paid by them for materials and supplies of all kinds entering into the construction and operation of a railroad for 5 years previous to June 30, 1914, and in some instances for 10 years, also the cost of certain kinds of labor. The prices called for were ordinarily those paid for four different purchases each year which were indicated by the order itself and not left to the selection of the carrier. The carrier was required to state the money payment which had been made. No estimate was permitted, or, if any estimate must be made of any part of the cost, the fact that it was an estimate must be stated. This return was prepared by the carrier from its records and sworn to."

The selection of June 30, 1914, as the pricing date was in some respects an accident. The valuation forces were assembled in the latter part of 1913 and the first part of 1914, and when Order No. 14 was issued, it was practicable to collect prices only up to June 30, 1914. The World War had not begun at that date, and many people thought that the economic level of prices as of that

time would constitute a fairly stable basis upon which to predicate the present value of railway properties, in so far as rate-making was concerned. At the close of the Nineteenth Century, prices had declined to the lowest point in one hundred years, but there had been a continuous and substantial recovery from 1900 to 1915. The European War began on August 1, 1914, the United States declared war on April 6, 1917, and what is now known as the great "World War", which extended over the period from August 1, 1914, to November 11, 1918, radically changed the economic situation so that prices advanced more than 100% up to 1920, and, even now, after five years of peace, the economic level of wholesale prices is 60% above that of 1914.

The World War Changes Values

This situation was not, and naturally could not be, foreseen at the time the valuation was started, and it remains to be considered how the "present value" of common carrier properties should be determined at the present time. The Supreme Court has pointed out in the Southwestern Bell Telephone Case, No. 158, October Term, 1922, decided May 21, 1923, that proper weight should be given to present prices. The Court said:

"Obvious, the Commission (Public Service Commission of Missouri) undertook to value the property without according any weight to the greatly enhanced costs of material, labor, supplies, etc., over those prevailing in 1913, 1914 and 1916. As matter of common knowledge, these increases were large. Competent witnesses estimated them as 45 to 50 per centum. * * *

"It is impossible to ascertain what will amount to a fair return upon properties devoted to public service without giving consideration to the cost of labor, supplies, etc., at the time the investigation is made. An honest and intelligent forecast of probable future values made upon a view of all the relevant circumstances, is essential. If the highly important element of present costs is wholly disregarded such a forecast becomes impossible. Estimates for to-morrow cannot ignore prices of to-day."

Final Value

The Interstate Commerce Commission has issued a large number of tentative final valuations. The "final value" of the properties is divided into two parts: A final value is being determined of the railway property "held for and used in the service of transportation", and separately the value for "the property held for purposes other than those of a common carrier". The first is commonly called a value for rate-making purposes, and the second a value of the non-carrier property.

The Federal valuation work has reached a stage where it is possible to forecast in a general way the relation of "Final Value" to the investment accounts of carriers. Obviously, the present value of some carriers is higher, and of other carriers lower, than the investment account. However, speaking generally, it is highly probable that the aggregate values of the railroads of the United States, including both common carrier and non-carrier property, as found by the Interstate Commerce Commission, will substantially equal the capitalization. The Commission in 1920 held in *ex parte* 74 that the tentative final aggregate value of the steam railroads is $18 900 000 000, and this value, which is the rate-making value, is very close to the investment shown on the

books. When the final aggregate value of all common carrier and non-carrier property of the railroads has been determined in accordance with Section 19*a* of the Interstate Commerce Act, the prospects are, as indicated by the tentative final valuations already issued, that the "present value" will be substantially the present total capitalization.

This being the case, the question is: What will be the effect of Federal regulation on the future development of railroads? The present value of the property is fundamental in connection with the various phases of public regulation. The Commission controls the issuing of future railroad securities by interstate carriers, the regulation of their car supply and distribution, the joint use of terminals, the construction of new lines, and the abandonment of old lines. The Commission is required to prescribe rates so as to enable the carriers as a whole, or in groups, selected by the Commission, to earn an aggregate annual net railway operating income equal to a fair return on the aggregate value of the railway property used in transportation. The Commission decided in 1922 that 5¾% is a fair return on the aggregate property value of steam railroads. Thus, it appears that the value of the property is fundamental, whether the question at issue is a reasonable schedule of rates, capitalization, consolidation, depreciation, recapture of excess railway operating income, joint use of terminals, construction of new lines, or division of joint rates.

National Welfare Depends on Transportation

It is likely that the growth of the main-line mileage of steam railroads in this country will proceed at a slow rate in the future. New lines cannot be constructed without the approval of the Commission, and it will be necessary to show that the public necessity requires the construction of the new road. In this connection, the *Engineering News-Record* of April 26, 1923, states what may properly be called a correct National policy in connection with railway development:

"The main theme that ran through the addresses at the Delaware and Hudson centennial deserves repetition—indeed, cannot be too often repeated: That efficient transportation pushed aggressively ahead of industrial and agricultural development, is just as necessary for the maintenance of our prosperity and our national welfare to-day as it was for the welding together of our nation and the encouragement of its growth in the last century."

Consolidation

The consolidation of railroads into a limited number of large systems is vitally related to the valuation. The Commission has held hearings in different parts of the United States at various times during the past fourteen months, and this fact indicates the careful study which is being made of the important question of consolidation. The hearings have not yet been closed and the record remains to be finally completed before any decision can be announced by the Commission. The Act states that:

"The Commission shall as soon as practicable prepare and adopt a plan for the consolidation of the railway properties of the continental United States into a limited number of systems.

"The value of the properties sought to be consolidated shall be ascertained by the Commission under Section 19*a* of this Act, and it shall be the duty of the Commission to proceed immediately to the ascertainment of such value for the properties involved in a proposed consolidation upon the filing of the application for such consolidation."

It has not yet been determined how many consolidated systems will finally be approved, but public discussion has centered on twenty. Dividing the 260 000 miles of steam roads by 20, shows that the average size of each system, under this plan, will be about 13 000 miles of main line. Thus far, discussion on the subject of consolidation has proceeded on the basis of the economies incident to size, or extent, but there has been no discussion of the disadvantages and lack of economy which may be experienced if the systems are too large. It is an important question susceptible of scientific determination whether there should not be, in the interest of the public service, more than twenty railway systems. This phase of the question has hardly been touched so far in the discussion of consolidation.

Samuel Rea, Hon. M. Am. Soc. C. E., stated before the Interstate Commerce Commission:

"* * * as his conclusions that the real test of successful consolidation was that efficiency and economy should be increased; that the initiative of management and operation should be preserved; and, above all, that the net earnings should be sufficient in normal years to earn a fair return on the property investment, so that sound credit may be maintained to provide adequate transportation facilities."

This is sound public policy. There are a number of roads such as the Bessemer and Lake Erie; Buffalo, Rochester and Pittsburgh; and Richmond, Fredericksburg and Potomac, the efficiency and economy of which may not be increased by consolidation, nor their initiative of management and operation fully preserved. Where properties are managed efficiently and economically in the public service, it would not seem to be desirable to force them into a consolidation merely for the purpose of dividing the roads into twenty systems. The subject of consolidation is so great, and involves so many considerations, that the public interest requires its most careful and extended consideration.

Affirmative Duty of Interstate Commerce Commission

The railways of this country are in a period of transition. Before the passage of the Transportation Act, the control exercised by Congress through the Interstate Commerce Commission was primarily for the purpose of preventing injustice by unreasonable or discriminatory rates against persons and localities, whereas under present conditions the new measure known as the Transportation Act imposes an affirmative duty on the Interstate Commerce Commission to fix rates so that carriers will earn an aggregate annual net railway operating income equal to a fair return. The Act also requires the Commission to take further important steps to maintain an adequate railway service for the people of the United States. All future regulation is to be based on a consideration of the property, its nature, classification, extent, use, and value. The railway companies will find it necessary to maintain

adequate technical staffs for the purpose of studying constantly the value of the property in its relation to a reasonable return, division of joint rates, joint use of terminals, capitalization, and other phases of the regulatory problem. In the future, it will be necessary, much more than in the past, for railway companies to do more work in the line of scientific research, and to submit this data to the Commission in order that the provisions of the Transportation Act may be reasonably carried out. There is a large field of usefulness for the engineer, accountant, statistician, and economist.

Co-operation is Essential

The effect of future regulation on the development of railways will depend, in large measure, on the thoroughness of the study which is made of the various phases of the railway problem. The Commission is obliged by law to predicate its decision on the record developed at hearings. The Transportation Act places such a great burden on the Commission that it will not be possible for its forces promptly to prepare the data needed by the Commission, and it will be necessary for the railway companies to organize an adequate force for the proper study of the problem, and to prepare and present to the Commission the scientific data which are absolutely essential as a basis for a proper decision in the various and multitude of issues which will grow out of the interpretation and enforcement of the Transportation Act. These issues involve the prosperity of one of the three greatest industries in America, the railway business, with a capitalization of $20 000 000 000.

Success Depends on Scientific Research

The public interest requires a reasonable regulation of the transportation business, and the people are well satisfied with private ownership of railways under public regulation. The Interstate Commerce Commission has done a wonderful work in the past and as the experience of the past is the only safe guide for the future, it may confidently be expected that future regulation will be highly beneficial, both to the public and the carriers. The railway problem is so great as to require for its proper solution the complete co-operation of the Commission, the railway companies, and all interested public bodies, to the end that the essential engineering, accounting, statistical, and economic data, on which all decisions must be based, shall be ascertained, analyzed, and presented to the Commission. The Transportation Act imposes an affirmative duty on the Interstate Commerce Commission to fix rates so that carriers will earn an aggregate annual net railway operating income equal to a fair return, and also requires the Commission to take further important steps to maintain an adequate railway service for the people of the United States. Future regulation based on the results of scientific research in the field of transportation, will inspire confidence alike in the owners as well as the users of railroads, and the maintenance of an adequate National railway service will be assured for the benefit of the public.

CONSOLIDATION OF RAILROADS

By Charles A. Morse,* M. Am. Soc. C. E.

The clause in the Transportation Act, calling on the Interstate Commerce Commission to consider the question of the consolidation of the railroads of the United States into not more than twenty systems, arranged so as to furnish competition between systems, and so as to allow each of the various systems, as a whole, to earn at fair rates a fair return on the value of the property, was the result, apparently, of the effort on the part of the Railroad Administration to hold the railroads in the hands of the Federal Government after the close of the World War. Some members of Congress favored such continuance of Federal control and operation, and by throwing this sop to them, it apparently was felt that they would vote for the Transportation Act.

It was not realized at the time of the passage of the Transportation Act how disastrous and expensive the experiment of Government operation had been, nor was it fully realized at that time how far-reaching the after effects of such operation had been on the railroad companies and the public.

Developments since that time have shown that the working conditions imposed on the railroad companies, to say nothing of the increases in wages that were made—most of which were the result of imposition on the Federal Government by Union Labor leaders, who were taken into the bosom of the Government with the mistaken idea that if this was not done, Union Labor would not be loyal in the time of the Government's need, which idea was fostered by such leaders—have worked a hardship not only on the railroads but on the public and finally culminated in the strike of the mechanical crafts during 1922 against a decision by a wage board which was created by the Transportation Act.

There is no question but that the wages and working conditions put into force by the Railroad Administration had much to do with the increase in the cost of living, as such wages were much higher than were being paid throughout the country at large, and made it necessary for the farmers, merchants, contractors, and manufacturers to increase the wages and shorten the hours of labor of their employees, with the resulting increase in cost of living. Time has made this fact apparent to the public which now recognizes that Federal control of railroads was even a greater disaster to the country than the war itself, as a longer time will be required to recover from the bad effects.

The spirit of paternalism that has gradually developed since the first Act to regulate big business, and especially the railroads, is the result of that element in human nature that makes every one who is given a little authority want to increase that authority indefinitely.

To-day, no one denies that regulation of great industries is desirable to prevent them from developing into monopolies, but Government officials and politicians are not content with regulation limited to that extent. The former crave power and the latter see the opportunity to extend their patronage and thus to extend their tenure of office, and they have encroached little by little,

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until now they have reached the point of encroaching on management of the properties, and with no actual knowledge or experience, they try to dictate the details of management.

The greatest danger to-day lies in this attempt by inexperienced Government officials to dictate the management of the great industries of the Nation. The idea, as expressed in the Transportation Act, of consolidation of the railroad companies of the country into artificial groups is along the same line. The railroads of this country developed along rational lines up to the passage of the Sherman Act, which forbade consolidation of competitive lines. The idea was all right, as it was an attempt to prevent monopoly, but, like many laws, it was interpreted too literally and prevented many consolidations which would have been beneficial to the stockholders and to the country served.

Now, comes an Act which proposes forcibly to consolidate the lines, under a scheme by which the well located and well managed railroad that has become a dividend-paying institution, must take over lines that, due to poor location, and possibly past bad management, do not earn anything for their stockholders. Presumably, the combined net earnings of the consolidated system must be divided, in proportion to a value of the several properties fixed by the Government, which means that the paying property must give a part of its profits to the stockholders of the poorer properties.

Why should the stockholders of prosperous railroads donate to the stockholders of roads that do not earn a fair return? Why should not the prosperous bankers, merchants, manufacturers, farmers, and others who have made a good year's earnings be required to donate to the unfortunate stockholders of non-dividend paying railroads? Simply because it is popular to consider the railroads, especially if they are dividend paying, as the property of "Wall Street", whereas, in fact, only a small proportion of their stock is held by New York bankers, or "Wall Street" operators. The great bulk of the railroad stock is owned by the small stockholders scattered all over the world, with a considerable part owned by employees of the different railroad companies, and widows and orphans of employees. It sounds better, however, and helps work up more sentiment against the railroads if the public can be made to believe that "Wall Street" bankers are being compelled to contribute to the earnings of the poorer railroads out of earnings that they have received from the dividend-earning roads.

It may be claimed that dividends are not affected by this requirement, and literally that is so, but, in fact, any surplus over dividends belongs to the stockholders and although it may not be paid out in dividends, it is utilized on improvements to the property that enhance its value and permit greater economies in operation. Through this means and the creation of a surplus, the dividends are made more certain in the case of bad years either of earnings or losses by floods and other calamities that occur from time to time. The Biblical saying that "To him that hath shall be given, but from him that hath not, shall be taken away even that which he hath", is particularly applicable to the railroads, for those railroads that can earn a surplus

can utilize that surplus in making improvements that will permit of cheaper operation, whereas those that cannot earn enough to pay dividends on their stock, not only have no money with which to effect economies, but, also, owing to their poor credit, have to raise the money required for necessities by short-time loans at a high rate of interest, and they cannot afford to use this high priced money for the purpose of the refinements that help to lower their operating costs. If the average earnings of all the railroads were such as to permit the earning of 8% on their common stock, it would allow the majority of the railroads to utilize the amount over and above a fair dividend rate on improvements that would lower operating costs, and the point would soon be reached where they could reduce their rates and still continue to earn the 8 per cent.

For the last twenty years the railroads have been faced with the demand for better service, higher speed, with automatic signals and other devices to permit doing this with safety, and a constant decrease in rates, fixed by State and Interstate Commissions, and, at the same time, a demand for better stations, track elevation, separation of grades—both between railroads and between railroads and public roads—assessments for public improvements, and, in addition to all these, constantly increasing taxes. In order to try to comply with these demands the railroads have had to provide heavier power, larger freight cars, steel passenger coaches, and baggage cars. The effect of the heavier power and equipment has made it necessary to strengthen the roadbed, use more ties per mile, increase the weight of rail, increase the depth of ballast, and insert ballast where it was not needed for the lighter power. Following this has come the necessity of scrapping steel bridges before more than half the life as originally estimated had expired, and replacing them with heavier bridges designed for the present power plus an estimated increase during the life of the structures, the installation of larger yards and longer passing tracks; longer turn-tables and transfer tables, larger round-houses, larger pits in machine shops, new machinery to do the work on the large equipment, and many other costly changes and improvements.

Railroad companies with a surplus and good credit have been able to follow this program more rapidly than others, whereas some of the poorer earning roads have been able to do but little of this work, hence their operating costs are very high.

The average railroad company, however, has made good progress along these lines, and if such roads could be allowed greater earnings, they would soon complete the circle and have but little of this expensive work to do, and their operating expenses would show a decided reduction.

The railroad companies are also hampered by the present accounting rules of the Interstate Commerce Commission under which there is a charge to Capital Expenses for every renewal that is made, even if there is no addition or betterment resulting from the renewal. This has come about through the efforts of the Interstate Commerce Commission to reduce rates, and an attempt on its part to justify the reduction by charging to Capital Account Expenses that which should properly be charged to Operating Expenses, thus keeping

down the apparent cost of operation. The result is a constant increase in the fixed charges and a decrease in net earnings. There can be only one result from such a policy, that is, an increase in the capitalization of the railroad companies to a point where they cannot meet their fixed charges, to say nothing of paying dividends on the stock.

During past years, it became a custom to take for granted that once a railroad always a railroad. The reason for the prevalence of this idea is not plain, but it results probably from the fact that in early days much of the railroad development was in a new country. The railroads were built across public lands and, in order to develop the country, the Government granted lands, in addition to the right of way, as a bonus. In later days, it was also the practice for cities and townships to vote bonds to the railroad companies in order to induce them to build branch lines. To-day, however, little of either practice is being followed, and there has been a gradual change in ideas. Many non-paying branch lines have been taken up, and if bonds were given on such lines, they have been repaid to the municipality or township that voted them.

One hears a great deal about what the Government or the public has done for the railroads, that makes them under enduring obligation to the public. What are these things that the Government has done, that are of such enduring value to the railroads? The first is the "right of eminent domain". Well, what does this consist of. It consists of the power to acquire the right to cross a piece of land, regardless of the will of the owner, but only after paying to the owner the value of the land taken and for any damage caused to the remainder of his property by the construction of the railroad across his land. In other words, an individual cannot stand in the way of a public improvement that is for the good of the public at large. This is of greater benefit to the public than it is to the railroad, because without this right no railroads could be built, therefore, there would be no railroad company to be benefited or injured. Under its charter, the railroad company is also given the right to cross public roads and navigable streams, but adequate facilities must be provided for the passage of all traffic over these roads or on the rivers. This is the extent to which the Government gives right to railroads in excess of what it gives to any corporation, and, in return, facilities for transportation are obtained, which give a value to the land and to the industries that far exceeds anything that the public gives up, as all it gives is a privilege, provided it is paid for.

Now that it has been shown that the public or the Government has given nothing to the transportation companies but what has been repaid many times, and now that it is being recognized that there is no reason why a railroad that cannot earn a fair return on the investment cannot be abandoned, why should not the railroads be considered and treated as other industries? If the railroads, through original faulty location or through changes in traffic routes which they cannot control, or for any other reason, cannot earn a fair return on the investment, permit them to go into bankruptcy and be sold; permit the owners to get what they can out of them, not allowing receivers to float certifi-

cates, except with the consent of the bondholders. In other words, treat the railroads as any other industry is treated.

There are about three hundred failures per week reported by Dun's Commercial Agency, which shows plainly that many industries that promised well enough to warrant the investment of the public's money failed to prove successful. Why, make an exception in the case of a railroad? The idea that a railroad had to be operated regardless of loss has been one of the causes of many railroads not being able to earn a fair return, due to the fact that many branch lines built when the railroad was small and needed feeders, are so near the market that the haul from these branches, under the present regulation of freight rates, causes a loss to the railroad. Such lines should be abandoned.

A discussion of the transportation problem to-day cannot be confined to the railroads. The development of the gas engine and its application to the automobile, the motor truck, and the passenger bus, with the resulting construction of good roads, and particularly of hard surfaced roads, has injected a new element into the transportation problem that must be considered seriously. Motor vehicles are now the competitors of the railroads, and will and must be allotted their proper place in the development of the transportation facilities of the future.

Highways are built at the expense of the public, either by bond issues or by the application of motor and gasoline taxes. When highways are financed by a bond issue, the railroad property as well as other property is the security for the bonds. Whether or not the interest is paid from the motor and gasoline taxes, the money paid for interest, maintenance, and upkeep of such highways is diverted from application to the other expenses of Government, which means an increase in taxes on all property.

The railroads are regulated in every way that the fertile mind of politicians can think of, whereas their competitors are free to charge what they please for services, both as to passenger fares and freight rates and, in addition, are granted the free use of the roads and the streets which are public property, and maintained at public expense.

On many railroad branches, the companies are compelled to maintain passenger service which does not pay the cost of the wages of the train crews, to say nothing of the upkeep of the equipment, and the fuel and maintenance of the railroad. In bad weather during the winter such lines get a little business, but in good weather it is all carried by the automobile and motor buses. In addition to this, a large percentage of the freight that formerly was handled on short branch lines is now hauled by motor truck. All this should be considered in any attempt to analyze the transportation problem of to-day. It is a question if it would not be proper to abandon many of the short branches of the railroads, especially where there are good roads. There is no question but that the passenger train service on all these branches should be reduced to a daily passenger train each way, and, in many cases, to a daily mixed train each way.

Instead of all the hearings and discussions regarding the consolidation of railroads, it would appear to be more rational to appoint a commission to study the whole transportation problem and ascertain whether a proper allocation of the handling of business between motor cars and the railroads could not be devised whereby the railroads would be relieved of a large amount of unnecessary train service and the motor cars assigned in a regular way to the business that is already being handled by them and held responsible for taking care of that business instead of the railroads being required to furnish a service that is unnecessary and is not utilized.

A railroad system is like a tree; when it is small, it requires feeders to keep it alive, and these feeders are comparatively close to the foot of the tree, or to its roots. As the tree grows, however, these small branches and feeders drop off, until, on a tree such as an elm, that is 50 ft. high, there will be no small branches within, say, 20 ft. of the ground, but there will be several large branches that leave the trunk 15 to 20 ft. from the ground, which, in turn, have no branches leaving them for 10 or 15 ft. from the junction. Out near the ends of these large branches will be many small branches that feed the large branches, which, in turn, feed the trunk of the tree. To be healthy, a railroad must be similarly constructed.

With the present rate system, all freight from small branch lines is delivered to the main line at a loss, and if the haul is too short between the junction point and the market, the business is handled at a loss. The business that pays the railroad is that which gives a sufficiently long haul after the freight reaches the main line, or a long feeder line, to make up the branch-line deficit and a fair profit in addition thereto.

There are many railroads that are what might be termed "light-headed". They have too many branch lines that produce a deficit on account of being too near the market and too few branch lines at the end of the trunk lines that have main-line haul sufficient to produce a profit. Consolidation of the railroads will not cure the disease, what is needed is the pruning knife.

Again, a railroad to be operated economically, cannot afford to maintain too many trunk lines that serve the same section of the country. Such lines should not be less than 50 miles apart and 100 miles is a better distance. The territory for 50 to 100 miles on either side of such a trunk line should be fed by branches that lead in a general way toward the market for their products.

A typical system—if it could be started now—would be of a herring-bone type, with branches coming into the main line at an angle of 45°, such branches leaving the main line about 100 miles apart and being about 100 miles long—this would serve a country about 200 miles in width. By this plan, the one main line could be maintained for heavy power and high speed, and the branches could be maintained as light lines at about one-half the annual cost per mile for maintenance as that required for a main line.

Any attempt to consolidate present existing lines would result in too many parts of the consolidated system being maintained as main lines, and

with too many branch lines that would connect with the main line at such an angle, or from such a direction, as to make a back-haul on the traffic.

If the Transportation Act could be amended to permit consolidation by railroads, with the consent of the Interstate Commerce Commission, regardless of the number of systems that would ultimately result, and eliminating any preconceived system of consolidation, there would be many consolidations that would be to the best interest of the public and the railroads. This would be especially true if this talk about forced consolidations and this scare head-line that is being worn threadbare, regarding the ultimate operation of the railroads by the National Government, would be discarded.

Many railroads are being operated that should never have been built. Many of the smaller roads were built with the intention of forcing some large railroad company to buy them at a profit to the promoters and many were built to meet conditions that have changed since their construction. Parts of many of these roads could be utilized to advantage by some of the larger and more prosperous companies, and if they were closed down and sold out, these parts would be bought by the railroad companies that could utilize them; but just as long as there is a chance to have the Government buy them, they will be operated as long as they can earn the interest on their bonds. Some of these railroads are in communities where there are no other transportation facilities, and where it will work a hardship on the community if the railroad is abandoned. In such cases, the railroad should be permitted to increase its rates sufficiently to give a fair return on its value, for, as a rule, the community would rather pay such increased rates than have the road abandoned.

One point should be brought out in connection with the threat which railroad baiters like to hold over the railroad companies, to the effect that if they do not do this or that, they will be taken over by the Government, and that is, in regard to taxes, special assessments, and also such improvements as track elevation, union depots, new passenger stations along the line, etc., the demand for which is constant and accompanied by threats of diversion of business. During 1922, the railroads paid more than $304 000 000 in taxes, which are increasing every year. Every school district throughout the West depends largely on the railroad taxes to take care of its school expenses. With Government ownership of railroads, there would be no taxes paid on the railroads, any more than there is on the Federal buildings. This also applies to special assessments for sewers, paving, drainage districts, and the innumerable assessments that are levied on the railroads to-day. New station buildings would come only through Congressional favor, and would be in the "pork barrel" class.

Consolidation of railroads will not tend to reduce cost of operation; any small saving in the salaries of general officers, will be more than overcome by the decreased efficiency of trying to handle so large a property, so widely scattered, by a single organization and with the handicap of lack of local authority.

There is a possibility of a saving by the consolidation of equipment so as to reduce the amount required by the railroads as a whole, but the experi-

ence during Federal control in regard to maintenance and upkeep of equipment when scattered over the country does not lend much encouragement along that line.

The solution of the transportation question is, to let the railroad companies operate unhampered by "soap box" orators as regards management; make them keep their accounts in a uniform manner, even to the smallest charges; let them handle the labor question on the basis of supply and demand —as is done in other classes of business; let them make their own rates, based on competition, but with a minimum rate set by the Interstate Commerce Commission to prevent strong lines strangling weaker competitors by rate-cutting; and make them give the best service they are capable of furnishing.

The only cases which warrant public authorities in setting rates are those in which a utility is given a monopoly of the business. There is no more reason for fixing the rates of competing railroads than there is for fixing the rates for competing steel mills, flour mills, department stores, or even the grocer and butcher. If, at times, the railroads will make more than a fair return it will be because business is good and other people are making money. They will have to make rates that will move the business, otherwise they will have no business to move. Take all rate-making (other than that previously mentioned) and wage-making away from the Interstate Commerce Commission and State Railway Commissions, and let them devote their time to seeing that good service is given without discrimination. In other words, cut out politics, and get down to Nature's remedy for rate and wage troubles, which is based on the good common sense principle of supply and demand; supply of shipping facilities and supply of labor *versus* demand for shipping facilities and demand for labor. Cut out the artificial and get down to straightforward business principles.

The trouble with the railroads to-day is simply a case of strangulation. Take the noose from around their necks and make the crowd stand back and give them air and they will recover. It is not a case that calls for a surgical operation—all that is needed is the use of a little common sense.

CONSOLIDATION OF RAILROADS

By John S. Worley,* M. Am. Soc. C. E.

During the last fifty years almost continuously small failing businesses have been merged into larger companies and made commercial successes. Order has been brought out of chaos, operating losses turned into profits, decrepit property rehabilitated, overheads reduced, credit restored, service bettered, quality of products improved, and cost to the using and consuming public reduced, much of which has been attributed to consolidation.

The benefits which have accrued from these consolidations have been so great that some people recommend consolidation as a panacea for many or all commercial troubles, and some are so impressed by the benefits which come therefrom, that they propose to nationalize many of the industries.

The possibility of benefits which have resulted in other industrial mergers and the facilitating of certain aspects of Government regulation were the motivating forces which led to the advocacy and final adoption of a law anticipating the consolidation of the railroads of the United States. The certainty of success which would follow this step caused the authors of the bill, as first presented to Congress, to include therein a mandate to the Interstate Commerce Commission to enforce consolidation.

In finally passing the bill, Congress rejected the inclusion of a mandate, but instructed the Commission to prepare a tentative consolidation plan and gave it no direct power of enforcement, but a final veto power. There seems to be no possible doubt that the Act as passed is much better than that proposed.

For convenience of reference that part of the Transportation Act which deals with the consolidation of common carriers is quoted in full, as follows:

"(4) The Commission shall as soon as practicable repair and adopt a plan for the consolidation of the railway properties of the continental United States into a limited number of systems. In the division of such railways into such systems under such plans, competition shall be preserved as fully as possible and wherever practicable the existing routes and channels of trade and commerce shall be maintained. Subject to the foregoing requirements, the several systems shall be so arranged that the cost of transportation as between competitive systems and as related to the values of the properties through which the service is rendered shall be the same, so far as practicable, so that these systems can employ uniform rates in the movement of competitive traffic and under efficient management earn substantially the same rate of return upon the value of their respective railway properties.

"(5) When the Commission has agreed upon a tentative plan, it shall give the same due publicity and upon reasonable notice, including notice to the Governor of each State, shall hear all persons who may file or present objections thereto. The Commission is authorized to prescribe a procedure for such hearings and to fix a time for bringing them to a close. After the hearings are at an end, the Commission shall adopt a plan for such consolidation and publish the same; but it may at any time thereafter, upon its own motion or upon application, reopen the subject for such changes or modifications as in

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its judgment will promote the public interest. The consolidations herein provided for shall be in harmony with such plan.

"(6) It shall be lawful for two or more carriers by railroad, subject to this Act, to consolidate their properties or any part thereof, into one corporation for the ownership, management, and operation of the properties theretofore in separate ownership, management, and operation, under the following conditions:

"(*a*) The proposed consolidation must be in harmony with and in furtherance of the complete plan of consolidation mentioned in Paragraph (5) and must be approved by the Commission;

"(*b*) The bonds at par of the corporation which is to become the owner of the consolidated properties, together with the outstanding capital stock at par of such corporation, shall not exceed the value of the consolidated properties as determined by the Commission. The value of the properties sought to be consolidated shall be ascertained by the Commission under Section 19*a* of this Act, and it shall be the duty of the Commission to proceed immediately to the ascertainment of such value for the properties involved in a proposed consolidation upon the filing of the application for such consolidation.

"(*c*) Whenever two or more carriers propose a consolidation under this section, they shall present their application therefor to the Commission, and thereupon the Commission shall notify the Governor of each State in which any part of the properties sought to be consolidated is situated and the carriers involved in the proposed consolidation, of the time and place for a public hearing. If after such hearing the Commission finds that the public interest will be promoted by the consolidation and that the conditions of this section have been or will be fulfilled, it may enter an order approving and authorizing such consolidation, with such modifications and upon such terms and conditions as it may prescribe, and thereupon such consolidation may be effected, in accordance with such order, if all the carriers involved assent thereto, the law of any State or the decision or order of any State authority to the contrary notwithstanding.

"(7) The power and authority of the Commission to approve and authorize the consolidation of two or more carriers shall extend and apply to the consolidation of four express companies into the American Railway Express Company, a Delaware corporation, if application for such approval and authority is made to the Commission within thirty days after the passage of this amendatory Act; and pending the decision of the Commission such consolidation shall not be dissolved.

"(8) The carriers affected by any order made under the foregoing provisions of this section and any corporation organized to effect a consolidation approved and authorized in such order shall be, and they are hereby, relieved from the operation of the 'anti-trust laws', as designated in Section 1 of the Act entitled 'An Act to supplement existing laws against unlawful restraints and monopolies, and for other purposes', approved October 15, 1914, and of all other restraints or prohibitions by law, State or Federal, in so far as may be necessary to enable them to do anything authorized or required by any order made under and pursuant to the foregoing provisions of this section."

Careful contemplation of the foregoing quotation discloses its salient features.

The Commission is instructed to "adopt a plan" in which "competition shall be preserved as fully as possible" and, where practicable, the "existing routes and channels of trade and commerce shall be maintained". The plan must be such that as far as practicable "uniform rates" in competitive traffic

will yield "substantially the same rate of return upon the value" of the property used. Two or more rail carriers may consolidate all or a part of their properties into a single system if the "Commission finds that the public interest will be promoted" thereby, and companies forming these consolidations with the approval of the Commission are "relieved from the operation of the 'anti-trust laws' ".

In light of experience, one cannot but state that the law is good. It permits the voluntary consolidation of rail carrier property, and voluntary consolidations are the only ones which can be a success. When approved by the Commission, these acts of the railways are not subject to the "anti-trust laws". It requires the Commission to prepare in advance a complete and comprehensive plan in order that it may be fully informed on the subject, and, finally, it places in the hands of the Commission the veto power—the only power given the Commission—as a guaranty that "the public interest will be promoted by the consolidation".

The law makes possible all those benefits which have accrued to all other industrial mergers. As preliminary to the adoption of a plan, the Commission very wisely selected Professor Ripley of Harvard University to study the problem and to make a report thereon. He found and set forth the following three general requirements which must be observed:

1.—Competition, presumably in service, shall be preserved.
2.—Existing routes and channels of commerce shall not be disturbed.
3.—The financial aspect of such mergers shall be kept in view.

These principles—and properly so—are very broad; they are so broad in their scope that there is scarcely a phase of the problem but what could be classified under some one of the three.

To the three requirements of vital importance just mentioned, the speaker would like to add another, namely, the effect on the spiritual elements of the properties and organizations.

It may sound unusually strange for any one even to suppose that a railroad had a spiritual side and even more absurd to suppose that it was of any value. On careful contemplation, however, the speaker thinks it will be found to have a value almost inestimable.

Government operation during and after the World War, cynicism which followed the war, communistic and syndicalistic propaganda, honest differences of opinions between labor and railway executives, and similar things, have spread a cloud that has almost enveloped the spiritual part of the railway organizations. It is still there, however; the traditions on which these properties have been founded and through which they have lived are the very foundations on which success in the past and the future is based. The traditions and spiritual characteristics of a railway are the unseen forces which give to it its very life. Even with the section foreman and common laborer these things are much more than one would suspect.

From briefs and testimony which have been submitted to the Commission, preliminary to its adoption of a plan, it would seem that the law contemplated wholesale mergers. One is impressed by what seems more of an effort to

accomplish consolidations *per se* rather than to determine and execute what is really needed. Of course, this is not so.

The Commission has tentatively adopted nineteen general systems. At present, there are approximately 2 095 railway corporations in the United States. Of this number, there are, according to the Interstate Commerce Commission statistics of railways for 1920, 186 Class I railway companies that own 182 352 miles of the 263 831 total mileage. However, these statistics show that, at present, 961 of the 2 095 corporations—Class I and others—are operated or controlled so as closely to approximate operation by only 87 of the Class I railways. The mileage operated by the 87 systems is 235 233, or 90% of the entire mileage of the country. So it is seen that 90% of the railway mileage is already operated by not an inordinate large number of quasi-consolidations. The remaining 28 598 miles represents 1 133 railways, some of which should become an integral part of any consolidation plan and the remainder should be abandoned.

Consolidation is unification—the complete co-ordination, in large blocks, of every function of transportation. Unified operation within certain limits is certainly conducive to economy and efficiency, but that this principle holds true to unlimited consolidations, can properly be questioned.

The merging of American railways into nineteen systems would make for a more efficient use of the terminal facilities and yards. It would bring about the abolition of many off-line offices and would simplify and reduce the expenses of inter-company accounting. It offers an opportunity for the reduction or abandonment of inspection forces now necessary where there is an interchange of inter-line equipment. However, the issue is at once raised, regardless of inter-line exchange, as to the desirability of this inspection to insure equipment being maintained to the proper degree.

It has been urged that the combining of the railways into nineteen systems would result in large economies because of reduction in salaries of high officials. It is true that there would be fewer railway presidents, but there would also be many more general, regional, and divisional executives with their staffs. The nineteen presidents would certainly receive salaries far in excess of the average salaries now paid, and the total salaries of the general, regional, and divisional executives would be higher than at present. Arguments advanced for economies along this line appear to have little or no force.

It would seem that the standardization of equipment would offer a field for additional efficiencies and economies. It is found, however, that the size, class, and weight of equipment that is best for one railway is not the most efficient for another. The weight of evidence is in favor of limited standardization.

The short routing of freight and the routing of export traffic to the best suited ports, which would result by having nineteen systems, is a benefit against which there is no argument.

Consolidated train loads has received much attention as an advantage of the Commission's tentative plan over the present, but all who are familiar

with railway operation know that on every railroad consolidated train loads is a subject which has first place in the mind of every executive. It is not an innovation.

Much emphasis has been placed on the economies to be obtained by consolidation of purchases on the theory that supplies, materials, and equipment in large quantities can be made for a much smaller sum than otherwise. Those who are familiar with this important branch of railway administration know the fallacy of such an argument. During the last two years the speaker has had an intimate experience in both purchasing and selling for several industries of considerable moment and he wishes to state that he has found that purchases both large and small can be made practically on the same basis of price.

That Government regulation would be greatly facilitated by fewer railway systems there can be no question. The advantage of cars "at home" is one to be recognized. At present, however, this is being largely provided by the Committee on Car Service of the American Railway Association.

From the foregoing, it is seen that there are decided advantages to be obtained by a more complete unification of the railways. It is also seen that some of those benefits which have been suggested would accrue, already exist or become questionable.

The merger of the railways into nineteen systems automatically establishes "absentee management". Centralization has been lauded and much emphasis has been placed on the control of general policies which would be obtained thereby. Its advocates, however, recognizing many of the weaknesses therein, give extended dissertations on "decentralization so as to create on different parts of the consolidated system, distinct units of management, each of which would be virtually autonomous except in matters of general policy". One has only to go back three years to Government operation when we had this very type of railway administration. A most capable railway executive, recruited from one of the most efficiently operated properties, headed this organization, and railway executives of the highest character and broadest caliber filled every centralized and decentralized position, and it did not work.

Large organizations, such as those that would be necessary if the railways were brought into nineteen systems, have the serious handicap of obtaining executives, administrative officers, and employees by the "seniority" rule. To-day in many of the large railway companies it is one of the most serious problems with which the higher executives have to deal. Large organizations make it impossible for the higher executive to have personal knowledge of the abilities of his employees, therefore, seniority and not ability governs where vacancies or new positions occur.

Concomitant with wholesale mergers is dismemberment. Advocates of consolidations recognize that "such dismemberment should be rigidly minimized". The same effect which results directly when a property is "cut in two", obtains indirectly where one road is annexed and absorbed by another. Dismemberment directly or indirectly means destruction of tradition.

In the light of the controversy which has existed between railway labor and the executives, it might appear that all tradition and spirit in the great transportation systems had passed. This is far from true. Executives and employees alike receive much inspiration from the traditions of the road. "The Road of Anthracite", "The New Haven", "The Dixie Flyer", "The Century", are not empty phrases. The driving force of "Jim Hill", the kindness of "Ripley", and the vision of "Harriman" have inestimable value to those properties with which they are connected. The accomplishment of that almost insurmountable task of connecting Key West to the mainland is spoken of with pride by every employee of the Florida and East Coast Railway Company. One road recently found that the "single narrow gold band" which had been removed from some of its locomotives, was so valuable, that this stripe of distinction was repainted. No industry, railroad or other, can expect success that has lost its traditions or has none. The dismembering or bringing together of several railway systems tends to destroy traditions and spiritual life.

Had the nineteen systems as now proposed passed through the development period as did the railways of to-day, and had these same nineteen systems been conceived, organized, constructed, and operated by a guiding hand which had full knowledge at all times of the needs of this time, it is obvious that they would be superior to the present systems; but that the present systems, the results of 90 years of development, can be remade into nineteen systems, superior to the present or without very great loss, is indeed a grave question.

It must be recognized that this, like all other problems, will not remain dormant. What then would be a good policy to follow? The first step should be voluntary completion of the consolidation of the 961 railway companies into the respective 87 operating companies, into 87 real systems, each with a single operating system and a single financial structure. Contemporaneously, or as conditions warrant, there should be included in the 87 systems those of the 1 133 which are needed as transportation facilities, and the others which have no possible reason for existence should be abandoned.

The 87 strong systems will say that the inclusion of any of the 1 133 weak lines in their properties is a sacrifice for which there is no return. This is not entirely correct because these weak lines always have an indirect effect on the strong, and as the mileage absorbed will be less than 10% of the whole, it is difficult to be impressed by this argument. Public welfare demands some sacrifice by the individual. The acquisition of this small mileage of weak roads by the strong ones should be preferably by private agreement. In negotiating the agreement, it should be done with charity by the strong and without avarice by the weak.

To be healthy and permanent, all progress, commercial and otherwise, must pursue natural courses. Progress must be by natural evolution and not by legislative force. It is often necessary to have legislative bodies provide the means and machinery by which to make possible the evolution, but the actual changes must be by natural processes. The present 87 systems have met to a great extent all the requirements stipulated by Professor Ripley.

Consolidations are already in a great measure perfected and Congress by the passage of the Transportation Act has made it possible to complete legally these mergers, which should be done. The Interstate Commerce Commission is fully informed of the principles to be followed that the "public interest will be promoted" and by its veto power can stop improper combinations. The consolidations which have been started, with such new ones as conditions warrant, should be completed along a plan neither radical nor ultra-conservative, thus conserving all the traditions and other elements of value, by which processes it is suggested the "public interest will be promoted" the best.

PRINCIPLES OF TERMINAL STATION DESIGN

By Alfred Fellheimer,* M. Am. Soc. C. E.

Introduction

The scope of this paper is limited to the brief outlining of principles to be considered in evolving a proper terminal plan, and it is not intended to point out in detail the ways and means of its accomplishment.

A passenger terminal improvement represents perhaps the largest single expenditure the railroad company makes for an individual improvement, and the degree of skill with which it is planned to a great extent predetermines its future as an asset or a liability.

In addition to the obvious railroad necessities, the designer is usually confronted with numerous important conditions, such as the economic soundness of the project and civic or other requirements for the present and future. As each problem presents controlling features peculiar to itself, a plan carried out elsewhere cannot be successfully copied. The designer therefore, must rely on his ingenuity, skill, and vision in devising a plan which will completely achieve the desired objective and satisfy all requirements with due regard to their relative importance, so that when the details have been correctly applied, a vitalized, successful plan will result.

The Creation of the Basic Plan

Preliminary Considerations

The terminal in its broadest sense should provide an efficient instrument of service for the handling of railroad traffic, permit the full utilization of the by-products for revenue, satisfy the requirements of city development, and render public service in the largest measure.

Certain tendencies, such as (1) Electrification, (2) Relation of Rapid Transit Systems to the Long-Haul and Short-Haul Passenger Traffic, (3) Merging of Terminals, and (4) Identity of Interest between Railroad and Community, are controlling elements affecting terminal station design.

(*1*).—*Electrification.*—Electrification within the strictly terminal zone of some of the large American cities, has received a distinct impetus in recent years. Its advantages from a purely railroad operating standpoint would not ordinarily be sufficient to justify the scrapping of existing plant and equipment. If the terminal, however, is in a part of the city which is already desirable, or may be potentially so for commercial building development, electrification permits of an intensive use of the property which is not possible with steam operation. The use that may be made of overhead or air rights to produce revenue without serious effect on the operating facilities which may be placed at or below the street level may be sufficient, in conjunction with such other advantages as electrification may bring to the specific problem under consideration, to justify its fixed charges. One of the most striking illustrations

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of the intensive use of all property in and about a passenger terminal, is the development at the Grand Central Terminal in New York City.

(*2*).—*Relation of Rapid Transit Systems to Long-Haul—and Short-Haul Passenger Traffic.*—As most railroad terminals are inspired primarily by the necessity of providing for long-haul passenger traffic, the handling of short-haul (suburban) traffic should not be allowed to become a limiting factor in the life of the terminal. Suburban traffic generally develops faster than through traffic and often threatens to absorb an undue proportion of the terminal facilities. This situation is aggravated by the modern tendency of long-haul through travel to attain its peak load coincidently with the short-haul peak.

The serving of near-by suburban or urban traffic is logically the function of rapid transit systems, which in general have failed to keep pace with the unprecedented growth of many of the large cities. In consequence, an undue share of this traffic is forced into the railroad terminals.

To the extent that the volume of this near-by suburban or urban traffic is reduced, its terminal service facilities may be restricted, unremunerative business eliminated, and capital expenditure lessened, thus making available more space and capital, if needed, for greater development of the terminal service for long-haul traffic.

In view of these circumstances, it is clearly an advantage to divert as much as possible of the urban and near-by suburban traffic from the terminal. Consequently, definite consideration should always be given to the feasibility of arranging or of providing for co-operative trackage rights and physical connections between railroad and rapid transit systems, existing or proposed, outside the terminal limits, thus assuring relief of the terminal from the burden of this concentrated service, and affording the public, in the greatest degree, door-to-door transportation.

(*3*).—*Merging of Terminals.*—As serious public thought is now being given to large consolidations of railroad properties, consideration should be given to the anticipation of such consolidation and the changes involved in their accomplishment, including the merging of terminals.

This involves broad questions of policy and economics of operation. The value of the land that may be released is often one of the major arguments advanced in favor of such a project. Before deciding in its favor, however, due weight should be given to the possibility, by electrification, of the railroad use and commercial development jointly, through the utilization of the air rights thereby made available.

Given the opportunity, it has been demonstrated that business activities will center about an electrified railroad passenger terminal, in order that advantage may be taken of the accessibility of transportation and the potential business possibilities created by the movement of large numbers of passengers through the various approach thoroughfares. In addition, the desirability of the air-right space is increased by the continuous control of a single ownership.

Through the mutual reaction of these favorable elements, it is not unlikely that the values thereby created will be greater than those following the full release of the same property for non-railroad use.

(4).—*Identity of Interest between Railroad and Community.*—In principle, the interests of the railroad and the community it serves are, in the last analysis, the same, and the terminal plan should express such identity of interest.

Municipal and other public officials, therefore, should approach the solution of these problems as far as the elements which they themselves represent are concerned, in the spirit of whole-hearted co-operation, and likewise, the railroad companies, not only as concerns the public interest, but also as between themselves, where the terminal project affects directly or indirectly more than one railroad.

General Requirements

The preliminary examination must determine that the project satisfies the following conditions:

1.—That the improvement at the proposed site, as compared with other available locations, is desirable from the viewpoints of construction and operating costs, including car unit costs. This is particularly important for locations so restricted in area that double-deck structures may be necessary to secure the required capacity.

2.—That suitable development can be made in stages to meet the expected normal growth in the services involved for a sufficient term of years to justify the project.

3.—That the proposed improvement is desirable from the viewpoint of the municipality and in harmony with its plans for development.

4.—That the advantages offered to the public are sufficient to justify such concessions as may be required from the municipality.

5.—That the project, in its entirety, presents a sufficiently favorable economic aspect, free from insurmountable prior obligations, to insure its complete financing along rational lines.

6.—That the by-products of the development, such as the overhead or air rights, can be utilized in a practical and profitable way so as to absorb, or at least substantially reduce, the carrying charges of the improvement.

7.—That the project as planned is so sound and free from imposing burdensome conditions on the railroad company that controlling or governing bodies will readily approve it.

8.—That the improvement is of such type that adequate enhancement of land values within the terminal area will necessarily follow.

Specific Requirements

The foregoing broad principles being satisfied, the basic idea must be in harmony with the following:

Transition from Existing Conditions to Proposed Plan.—Except at new locations, the plan, in its general conformation, must fit in with existing con-

ditions to an extent sufficient to permit of gradual transition into the complete or final plan without serious disturbance of operation, and in such stages as will conform with the development of railroad traffic and contiguous property. Obvious economic and practical reasons make this imperative.

Balance between Benefits to Public and Cost.—It must strike a proper balance between the public comfort and convenience on the one side, and economy, both in first cost and subsequent operation, on the other. This insures good will on the part of the public, and efficient and liberal service on the part of the railroad company.

Simplicity of Plan Insuring Directness.—The general layout must be orderly and direct in the placement of its principal parts, because in a project of large dimensions and scope, freedom from disorder and confusion is in direct proportion to the simplicity of the plan.

Street Arrangement and Railroad Facilities Co-Ordinated.—The railroad facilities provided must co-ordinate with the complete development of streets and blocks throughout the terminal, conforming with the civic plans for unrestricted expansion of the city adjacent to or across the terminal area. This will benefit both the railroad company and the public.

Flexibility in Adjustment to Future Requirements.—Facility of adjustment to future requirements must be arranged, because the useful life of railroad facilities is limited by obsolescence rather than by physical decay. Such facilities therefore, can be considered stable or permanent only in so far as they are adjustable to changing conditions. This applies with special force to terminals which, in their initial stages, must be operated by steam.

Adequate Trackage in Approaches, Throats, and Yards.—Definite determination must be made of the adequacy of approaches, throats, and yards, to assure ample capacities of trackage, all in proper balance, thereby making possible a high degree of operating effectiveness.

Selection of Characteristic Basic Types

After the plan has been proved to be in accord with the preceding requirements, determination must be made of certain characteristic basic types, as follows: (*a*) Through or stub type of track facilities, as affecting train operation; and (*b*), head-house type of station facilities, as affecting station operation.

(*a*).—*Through or Stub Type.*—The designation, "terminal", although strictly applying to a rail or operating "terminus" only, is, in this paper, used as referring to a station of either the stub or through type of track facilities.

Through Type.—This layout, if the track facilities provide in part or whole for through train operation, is concededly best adapted for efficient and rapid train handling, and is, therefore, where choice can be made, the type to be selected, unless a careful investigation of all the elements affecting the correlated and dependent facilities, fails to disclose the necessary preponderance of factors in its favor.

Stub Type.—Where conditions permit, this type, if the train operation terminates at the station, can be given some of the special advantages of the through type by providing a loop or engine release arrangement.

In the stub type of terminal, the platforms and other facilities can be arranged at one level except in cases where there is a difference between street and track level. This results in advantages as follows:

1.—Highest total efficiency in operation and the greatest convenience to the public.

2.—Freer and faster travel on platforms, unencumbered by stairs or ramps.

3.—Practical elimination of vertical travel of passengers between streets and platforms.

4.—Economy in construction cost, maintenance, and operation.

Wherever possible, the short-haul (suburban) traffic, with its intensive service requirements, should be provided with means for through or continuous train operation.

(*b*).—*Head-House Type.*—A definite selection must be made of one of the three general types of head-house before proceeding with the consideration of the arrangements of the detail features.

1.—Waiting-Room Type of Head-House.—In this type the waiting-room is made the focal center of the station, with all dependent facilities, such as ticket office, baggage and check rooms, opening directly therefrom and with separate passenger concourse for access to train platforms. The Washington Union Station is an example. (This arrangement tends to make the main waiting-room a thoroughfare between the street and the trains.)

2.—Concourse Type of Head-House.—In this type a large general passenger concourse is provided for the mass movement of passengers, with ticket office and other dependent facilities opening directly therefrom, the waiting-room with its auxiliary facilities being placed adjacent to but separate from the concourse. The Grand Central Terminal, New York City, is an example. (This type tends to minimize conflict of foot-passenger traffic.)

3.—Composite Type of Head-House.—This type has a large room provided exclusively for the sale of tickets, checking baggage, and like dependencies, with separate waiting-rooms and passenger concourse. The Pennsylvania Station, New York City, is an example. (This type tends to create cross-currents of travel between the various station facilities.)

Elaboration of the Design

Traffic Considerations

Extreme Peak Conditions of Traffic not to Govern.—Although station facilities should be planned to accommodate anticipated traffic, including normal frequently recurring peaks, it is not essential to provide for occasional extreme peak conditions, because, in a well planned station, an overload can be carried by all facilities for short periods without undue operating stress or inconvenience to the public.

Foot Traffic Channels.—Natural and Direct.—The general arrangement should invite movement of foot traffic along natural and direct channels so that, as far as practicable, passengers may avoid crossing the main travel routes and the retracing of steps.

Where established lines of city foot traffic are permanently interrupted by the terminal construction, provision should be made to accommodate this traffic without interfering with the normal use of the station.

Separation of Suburban and Through Foot Traffic.—The separation of suburban and through traffic should be accomplished effectively in order to avoid confusion and to expedite the movement of both classes of traffic. It is not essential that entirely separate concourse, waiting-room, and general facilities be provided. It is necessary, however, that the main channels of circulation be completely separated.

Separation of Inbound and Outbound Traffic.—Although it is desirable to separate the passenger foot-traffic channels and allocate sections of the terminal facilities to inbound and outbound traffic, no physical division should be planned in the track layout that will limit interchangeability and elasticity.

Separate Inbound and Outbound Baggage Facilities.—The baggage facilities for receiving, delivery and storage should be separated. Trucking subways, bridges, and other passageways may be used in common.

Vehicular Traffic.—Adequate provision should be made for the public and private vehicular traffic in suitable relationship to station facilities.

Local Transit Contact.—In addition to access to streets, convenient entrances and exits should be provided for interchange of passengers with surface car lines or other local transportation systems.

Traffic Diversion to Be Avoided.—The plan should provide for direct contact with all natural points of entrance and exit, rather than force the diversion of traffic to points dictated purely by the necessities of the architectural composition.

Traffic Contact with Mail and Express Facilities.—Provision should be made for direct traffic contact by means of trucking and elevator facilities, with the passenger platforms.

Where this traffic is in solid trains, consideration should be given to its location outside the terminal.

Segregation of Freight Traffic.—Where the terminal plan includes provision for freight traffic, this part of the layout should be entirely segregated from the passenger facilities and, as far as possible, all freight driveways should be separate from the main streets or thoroughfares, in order to minimize the interference in the operation of these facilities with passenger and public traffic.

Station Facilities

General Requirements.—The various facilities comprising the station proper must be placed in the natural and orderly grouping which their logical related uses dictate. The individual sizes of adjacent facilities should permit modification, if future requirements so dictate, without seriously disarranging the general co-ordination of the plan.

The Passenger Concourse.—This concourse should be roomy and entirely enclosed with weather-tight gates at the train platforms. These train gates

should preferably be in a continuous line on one side of the concourse. The concourse should be free from confusing changes in direction; ample and direct access should be provided from the concourse to strategic street points and the various station facilities.

The Waiting-Room.—The waiting-room should be arranged to be conveniently accessible for patrons from the street and station facilities without inviting usage as a thoroughfare, and should have all facilities for the comfort and accommodation of waiting passengers located adjacent and readily accessible. The location should permit of adequate ventilation and daylighting.

The Ticket Office and Checking Facilities.—These facilities should be placed in contact with, but not encroaching on, the main routes of travel between streets and trains, so that persons not requiring these facilities may pass without conflict with passengers buying tickets or checking baggage.

Associated Facilities.—All working facilities should be provided with conveniences and equipment required to insure the full working efficiency and comfort of the employees.

Concessions.—Revenue-producing facilities conducive to the comfort and convenience of the passengers should be located along the main arteries of travel, placed so as not to reduce the effectiveness of station operation. Their arrangement should insure maximum patronage from the general public and railroad patrons, thereby enhancing their rental value.

Architectural Objective of the Design.—The elaboration of the architectural features of the design should reasonably express the purpose of the improvement and emphasize the relative importance of entrances, exits, and like features. Attention should be paid to mass effect which attracts the notice of the general public, rather than to details which are seen or appreciated only by a few. Economical consideration should be a definite aim throughout, including the avoidance of especially elaborate constructional detail.

Commercial Office Space in Station Building.—The station plan should impose on the office building no limitations which will exclude any essentials needed to assure successful competition with similar commercial buildings.

Overhead Buildings in Contact with Station Facilities.—Where the character of overhead buildings can be predetermined, as requiring contact with the station, freight, or other facilities, it should be provided for; otherwise, flexibility should be given, making possible future conversion to suit the requirements.

Platforms and Ramps

Platforms.—Platforms should be level with the car floor, especially for suburban service. If conditions compel the use of low platforms, provision should be made for future conversion to the high type.

Where the width of platform is restricted by the need for intensive development of the property, the minimum should permit passengers to pass freely between loaded baggage trucks when placed along either side of the platform.

Means should be provided to avoid trucking across platforms and tracks.

Baggage elevators should not be located in narrow platforms, except at the outer end. When placed at the concourse end, they should not obstruct circulation. The enlargement of platforms at the concourse end, known as the "midway", provides space for elevators, stairs, and similar facilities without encroachment on the concourse or interference with public circulation, and permits the use of several train-gates at one time in speeding the exit of arriving passengers.

Separate baggage platforms are not ordinarily necessary. The handling of baggage on passenger platforms causes slight interference with passenger traffic. Suburban trains carry practically no baggage. Inbound long-distance trains normally occupy the platforms for a considerable period beyond the short interval required to discharge the passengers. Passengers for outbound long-distance trains are so thinly distributed that no appreciable interference results. However, if such platforms are provided, they should be of ample width, as narrow ones will be useless.

The spacing of platforms and tracks, particularly if lines of columns are necessary, should be designed to permit ready re-arrangement of platform widths to meet future needs.

Column lines for superimposed structures, in the absence of controlling conditions to the contrary, should be located in the platforms instead of between tracks, thereby reducing danger to overhead structures, increasing the view for operation, adding to safety, and facilitating maintenance. Columns in platforms interfere only slightly with passenger movement, with small loss of space, whereas, if they are between tracks, the space is entirely lost.

Ramps.—Where the tracks and streets are necessarily at different levels, the vertical travel, if possible, should be by means of ramps, rather than by stairways. In general, ramps permit more rapid circulation, cause less fatigue, and minimize accidents. Where the foot of ramp extends several car lengths or more from the station end of a narrow platform, provision should be made to avoid backward travel of arriving passengers.

Track Facilities

A reasonable proportion only of the station tracks need be of sufficient length to accommodate the longest trains that present power can handle, plus an allowance for increase. Excessive rates of curvature and grades should be avoided as interfering with effective and safe operation, and as far as possible, tracks along platforms, especially of the high type, should be straight.

If overhead building construction is contemplated, the track spacing and location of special work should afford reasonably free opportunity for placing of columns and avoidance of long building spans.

Where conversion from steam to electric power in the future is a possibility, provision should be made to permit the installation of electrical features affecting the track and platforms.

Special Structural Requirements

In addition to the usual provisions for changes due to temperature, all buildings the rental value or use of which is adversely affected by excessive

vibration should be entirely separated, as to their foundations and other structural parts, from similar parts in other buildings or structures through which directly or indirectly the vibration due to rolling or live load may be transmitted.

Columns at track level, where necessary, should be protected by suitable collision piers, in order to prevent failure through derailment, and should never be in the direct line of the track immediately beyond a bumping post.

The choice of type of future electrification, if initial operation is by steam, should not be hampered by any structural limitations, such as insufficient head-room.

Auxiliary Facilities

Wherever possible, provision should be made for the location of all auxiliary operating facilities, such as signaling, central plants, sub-stations, and equipment, entirely separate from, but accessible to, the station facilities. In determining the proper location, due consideration should be given to the influence of all economic elements, such as land values, economy in handling supplies and waste material, and load distribution.

Checking or Proof of the Adequacy of the Design

General Considerations.—Averages and statistics derived from other terminals, although interesting and helpful, have no final determining value. The facts of record at the terminal under consideration must finally govern. Each facility must be tested by the actual local requirements.

Load Co-ordination.—Consequently, when the general design has been accomplished, it is imperative that the final test as to load co-ordination be applied to determine: That all parts are in balance; that no individual feature is under or over developed; and that all features will simultaneously reach the saturation point.

Analysis of Operating Capacities.—To accomplish this, an analysis should be made of the operating capacity of the approach tracks, throat tracks, and body tracks, as a proper balance of these facilities is of vital importance. Likewise, the relative values of practically all supporting facilities in the plan should be measured and balanced in order to safeguard the successful future of the development.

As an example, the size of the ticket office and the number of selling windows, can be definitely calculated as they have a fixed relation to the number of outbound passengers of all classes handled, which is determined, in turn, by the ultimate saturation point of the track facilities used in handling outbound cars.

Terminal Failures Explained.—It should be here specially noted that failure to check or prove the adequacy of the design along these lines, accounts for many of the faults and weaknesses in American terminals.

THE RAILROAD FREIGHT TERMINAL PROBLEM IN ST. LOUIS, MISSOURI

By Charles E. Smith,* M. Am. Soc. C. E.

About twenty-six railroads enter the St. Louis Industrial District which embraces a population of about 1 000 000. Including the terminal switching lines the District is served by about thirty separate railroads. Although resembling the railroad layouts at New York and Chicago, the situation at St. Louis is somewhat more involved by reason of the fact that full railroad service is rendered on both sides of the waterway (the Mississippi River), together with a heavy interchange across the waterway, whereas the service at Chicago is confined to only one shore of Lake Michigan, the Chicago layout resembling somewhat the East St. Louis layout. At New York, railroad service is confined largely to the west shore, which layout resembles to an extent the railroad situation on the east bank of the Mississippi River at St. Louis. On the west bank, however, St. Louis is served by a number of trunk-line railroads and by terminal switching companies which are really the St. Louis or west bank terminals of the east side lines.

In the early days, east and west railroads were connected across the Mississippi River at St. Louis by a number of car transfer ferries which continued in service until the river was bridged, but which thereafter were abandoned one by one until only one remains. The interchange of cars across the river, formerly effected entirely by car ferry, is now effected on three railroad bridges and one car ferry. Two more railroad bridges have potential capacity for heavy railroad traffic not now using them.

All east and west railroad rates are made to and from the east bank of the Mississippi River. Rates for service across the river and beyond are added to the east bank rates. Thus, St. Louis being situated on the west bank of the river, for many years paid, in addition to the east bank rates, the cost of crossing the river, first, by car ferry and, later, over the bridges. In 1907, an agreement was reached between the railroad companies and the business men that this excess charge or differential on shipments between St. Louis and Eastern points over the rates on shipments between East St. Louis and Eastern points, would be eliminated and the river-crossing charges absorbed by the railroad companies on all traffic originating in, and destined to, points more than 100 miles east of St. Louis, but that the differential would remain on traffic within that zone, which consists primarily of Illinois coal.

As the charge for river crossing and St. Louis delivery on Illinois coal amounts to 20 cents per ton, this is a very considerable advantage enjoyed by East St. Louis by reason of its position on the same side of the river as the coal, in contrast with the more distant location of St. Louis on the opposite side of the river from the coal.

* Cons. Engr., St. Louis, Mo.

Prior to the absorption of the differential on long-haul traffic in 1907, St. Louis business interests worked and fought for many years to eliminate the differential, and there is still a very strong sentiment in favor of eliminating the remaining differential on coal. During this period of strife, it has been difficult for the railroad companies to secure the rights they needed from the public for the development of their St. Louis facilities. The consideration of the grant of such rights has always been met by obstructionist tactics of those who would make the elimination of the differential a condition precedent to granting the roads any rights in the city. Consequently, to an extent, St. Louis business interests have been on a "hunger strike" as regards railroad facilities and service, by reason of the fact that although they have been continually offered improved facilities and service by the railroad companies, they have refused to partake thereof unless it is accompanied by recognition of the principle of the elimination of the differential.

On two occasions, however, business interests and the City authorities have provided additional river crossing facilities in an endeavor to secure the results desired. The Eads Bridge was built as an independent venture, from 1867 to 1874, having been placed in operation in 1874. It was soon recognized that the bridge would not be profitable in competition with the river ferries, and it was consolidated with a terminal company organized for the benefit of a number of railroad companies. That company was the nucleus of the present Terminal Railroad Association, which is a co-operative association operated in the equal interest of, and controlled in equal parts by, fifteen of the largest railroad companies in the district, but the facilities of which, including the Union Passenger Station, are open to its non-owners as well as to its owners, on equal terms and conditions. Although all the largest railroad companies have interests in the Association, each has developed its own terminals as well, and some of the individual terminals are quite extensive.

From 1889, when the Terminal Railroad Association was organized to succeed the former company, until 1902, it was controlled by less than one-half the trunk lines. In 1902, when the remaining trunk lines sought to combine in a separate terminal for competition with the other company, a truce was effected by the consolidation of both projects into one in the equal interest of fourteen large roads. Later, one more road joined. About ten smaller roads and two switching companies are not members. In 1890, a group of St. Louis merchants financed and built the Merchants Bridge and terminals and railroad connections in an endeavor to encourage the railroad companies to use that river-crossing facility in a manner that would wipe out the differential in rate between the two sides of the river. It soon failed of its purpose and in 1893 was turned over to the railroad companies that were in control of the joint terminal company by which it has been operated since in the equal interest of all railroads.

Agitation continued, however, for several years, until agitators were successful in having the citizens of St. Louis, after the Mayor had vetoed the project, vote bonds for the construction of a Municipal Bridge across the river,

which it was specified in the ordinance "should be and forever remain a free bridge", the intent having been to extend the free use of this bridge to railroad companies that would extend the East St. Louis rates to St. Louis. In spite of the fact that this bridge has been completed for six or seven years, it has failed of that purpose, although the highway traffic is very heavy. No railroad companies have yet used the Municipal Bridge for crossing the Mississippi River, and railroad executives have repeatedly stated that as long as the use of the bridge is contingent on the rate situation, the bridge will not be used for railroad traffic.

Because of these conditions, the transportation facilities of the St. Louis Industrial District, although tremendous in extent, have not been the result of a well ordered growth, but of haphazard developments, with the inevitable outcome that the river crossing service and the terminal service within the District are entirely unsatisfactory, both to the railroad companies and to the public. Two instances will suffice to illustrate the extent to which the St. Louis Terminals have failed to keep pace with requirements: (*a*) The Missouri Pacific Railroad Company has yards on opposite sides of the Mississippi River, about three miles apart, near the south city limits, connected by a car transfer ferry. The ferry is inoperative for a period each year by reason of low water and ice, and, at such times, the freight is detoured by Missouri Pacific engines over the tracks of the Terminal Railroad Association and the Merchants Bridge, a total distance of about 25 miles. This trip always consumes many hours because of delays; train crews have been tied up under the sixteen-hour law making this detour; (*b*) the Chicago, Burlington and Quincy Railroad Company has yards on opposite sides of the Mississippi River near the ends of the Merchants Bridge, 3 or 4 miles apart, connected by rails of the Terminal Railroad Association. Instead of sending its cars over this short route between its yards, the Burlington finds it expedient to send them 40 miles around, across the Missouri River at Bellefontaine Bridge and across the Mississippi River at Alton Bridge; the entire round trip of about 80 miles is usually made within 8 hours. As a result of these conditions, the executives of a number of large railroad companies requested the officers of the St. Louis Chamber of Commerce to undertake an investigation and to start the "ball rolling" for improved facilities. A committee of ten business men representing interests on both sides of the river, and three railroad executives, was appointed. After some consideration it was decided that a committee of engineers should be put to work. This Committee consisted of four representatives of the railroads and three representatives of the public. Of the seven engineers, five are members of the Society.

In addition to the engineers, the directors of three bureaus of the St. Louis Chamber of Commerce also served on the Committee. The speaker as a member of the Committee served as Consulting Engineer for the City of St. Louis and was also chosen as Consulting Engineer to the Committee to assemble the data, prepare the information, and write the report. The report

as printed contains nearly 400 pages, with 30 tables and 133 illustrations. The work of the Committee was summarized in conclusions and recommendations broadly classified under the headings of Unification, Mississippi River Bridges, Re-Routing Passenger Trains, Passenger Station Facilities, Classification and Interchange of Carload Freight, Team Tracks, Less Than Carload Freight, Grade Crossings, River Front Development and Electrification.

Passenger Facilities

St. Louis has only one passenger station, which is a Union Station for all railroads. This station which was built in 1892, has more tracks and less trains than the South Station in Boston, Mass., and has a capacity for handling a very considerable increase in number of trains. The facilities surrounding it were enlarged in advance of the Louisiana Purchase Exposition in 1903, since which time there have been only minor corrections and additions. Since 1903, however, there has been a very considerable change in methods of operation and volume of business. Heavier engines have made possible longer and fewer trains. Express and mail business has multiplied and the parcel post has been developed. Table 3 shows the volume of various classes of business transacted in 1905, 1910, 1915, and 1920. Note particularly the increase of 200% in express business, notwithstanding the parcel post.

TABLE 3.—Business Transacted at St. Louis Union Station

	1905.	1910.	1915.	1920.
Passengers (official figures not available) about.	.....	.....	.....	25 000 000
Passenger Trains	.....	108 952	101 395	93 281
Passenger Train Cars	618 814	561 266	544 517	602 496
Baggage (pieces)	2 209 037	1 829 839	1 509 275	1 831 132
Express (tons)	62 173	66 623	92 618	183 420
Mail (not including Parcel Post):				
Received (pounds)	8 440 888	10 107 087	13 122 257	18 011 301
Dispatched (pounds)	42 474 327	48 127 924	45 806 012	40 563 677
Passing Through	Cannot be obtained.			
Parcel Post:				
Received (pounds)	2 260 491	2 535 621	4 251 172	41 290 994
Dispatched (pounds)	1 883 116	1 849 427	10 274 827	53 299 045
Passing Through	Cannot be obtained.			

The Committee found that the Union Station was a beautiful structure, well situated, and conveniently arranged, but that the railroad companies should obtain a considerable area of undeveloped ground south and west of the Station and that attention should be given to plans for the following improvements:

Additional and improved public approaches, consisting of streets, street cars, and other transit facilities.

Park or plaza in front of the Station. This has been already provided for in the recent City bond issue.

Longer and wider station platforms.

Flatter curves on station approaches.

Engine facilities, passenger train car yards, and other passenger train facilities east of the Station near the business district to be moved west of the Station and very much enlarged on less expensive property.

A train yard to be provided for making up and breaking up passenger trains.

Increased and enlarged facilities for baggage, express, mail and parcel post, including buildings and tracks.

The removal of the present balloon type train shed and its replacement by a Bush or umbrella type train shed.

Plate IV is a map of the railroad layout in the vicinity of the Union Station showing, in the upper part, the present conditions and, in the lower part, the new layout that is recommended by the Committee. Table 4 is a statistical comparison between the facilities afforded by the present plan and by the proposed plan.

TABLE 4.—STATISTICAL COMPARISON BETWEEN PRESENT AND PROPOSED UNION STATION FACILITIES.

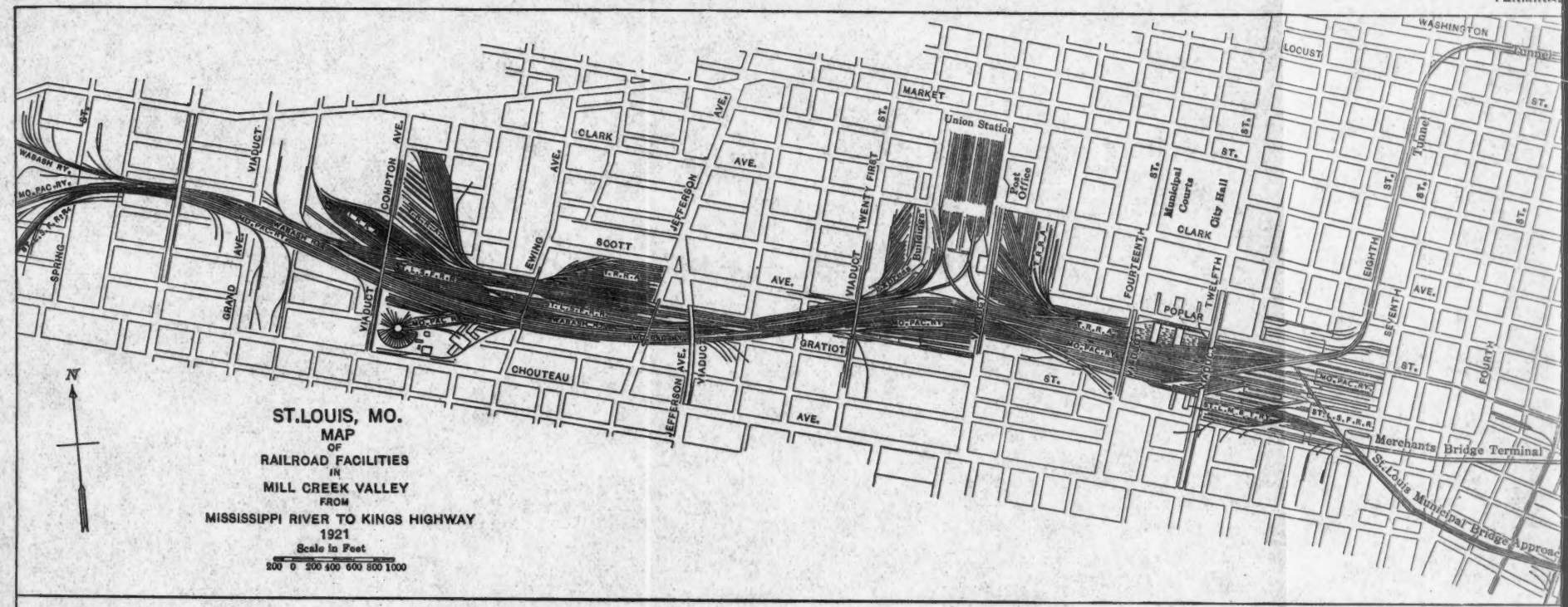
	Present.	Proposed.
Midway	60 ft. wide	100 ft. wide
Station Tracks	32	32
Length of Station Tracks	850 to 900 ft.	1 100 to 1 150 ft.
Approach Curves	15°	10°
Outbound Baggage Room	600 ft. long	800 ft. long
Inbound Baggage Room	9 000 sq. ft.	45 000 sq. ft.
Tracks for Baggage Cars	.....	12 cars
Mail and Express Buildings to be divided as required west of Station	4 500 sq. ft.	100 000 sq. ft.
Tracks at Mail and Express Buildings and Head End Yard	60 cars	150 cars
Train Yard	None	20—1 200 ft. tracks
Engine House Facilities	150 000 sq. ft.	350 000 sq. ft.
Passenger Train Car Yards	2 000 000 sq. ft.	4 000 000 sq. ft.
Team Tracks and Warehouses	500 000—12 acres	1 000 000—24 acres
Suburban Station	None	20 tracks
Grade from Twelfth Street to Merchants Elevated and Municipal Bridge	2%	1%

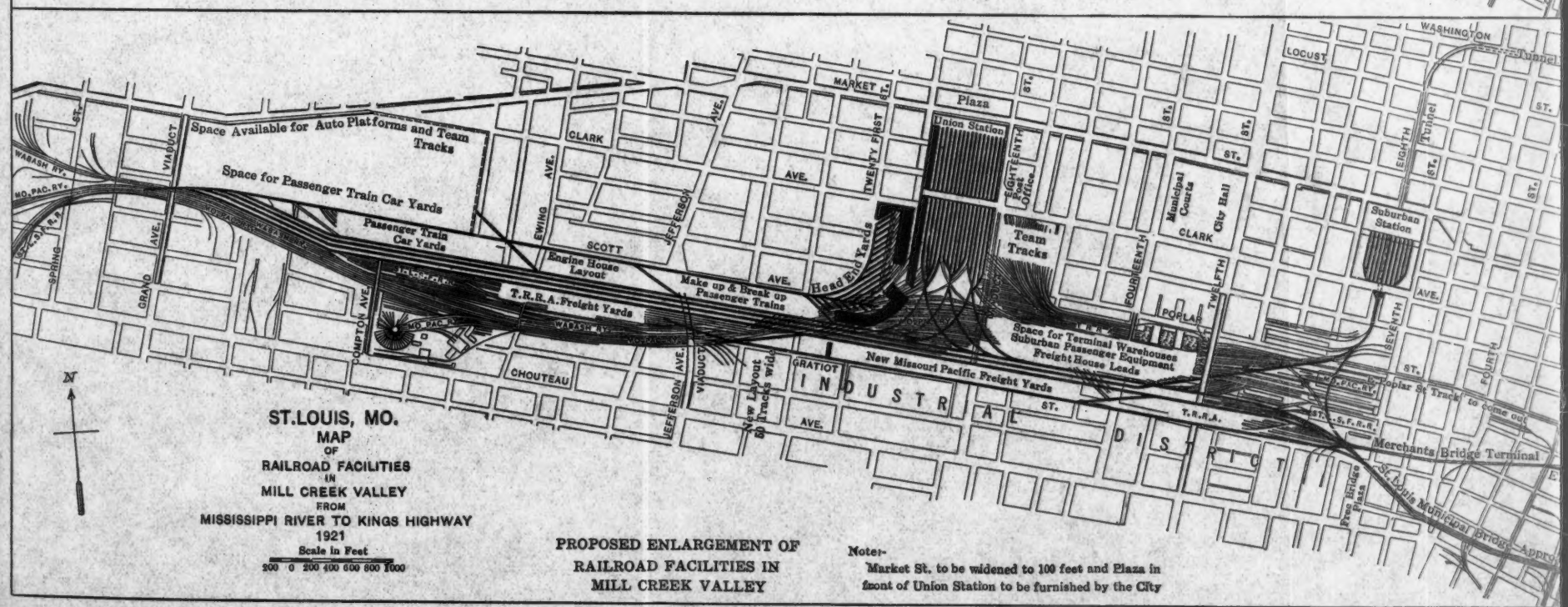
The necessity for considerable improvement in the present passenger train entrances for Eastern lines and the old style balloon train-shed of the Union Station has been graphically described by Frederich Simpich in the *National Geographic Magazine* in the following words:

"Even entering the town by rail over any of its 23 roads (22 of which enter the Union Station), your train seems to go reluctantly, grumbling, as if sensing its mean surroundings. In uncomfortable intimacy you fairly hug the back doors of endless squalid two-story brick houses, through whose uncurtained windows you glimpse the inner chambers of cheaply furnished homes, of crowded, unkempt flats where beds, sewing-machines, and dining-tables seem struggling for standing room.

"Across narrow courts lines are stretched, from which the family wash hangs wet and limp or pops in the wind like the myriad flags that dress a ship on gala days.

"On and on your train winds, twists, and squeaks, now passing grimy warehouses, abandoned livery and feed stables, breweries that cannot brew, on past gloomy coffin shops, past breakfast-food factories flinging giant signs to





PROPOSED ENLARGEMENT OF RAILROAD FACILITIES IN MILL CREEK VALLEY

Note:-
Market St. to be widened to 100 feet and Plaza in front of Union Station to be furnished by the City

ENLARGEMENT OF
D FACILITIES IN
CREEK VALLEY

Note-
Market St. to be widened to 100 feet and Plaza in front of Union Station to be furnished by the City

PLATE IV.
PAPERS, AM. SOC. C. E.
SEPTEMBER, 1923.
SMITH ON
TERMINAL PROBLEM IN ST. LOUIS.

a startled world, and yet farther along, over the elevated road, above rough, cobblestoned streets noisy with jolting trucks.

"Thus you proceed by jerks, jumps, and dusty, stifling waits, till you climb out under the vast, dirty, vaulted roof of a smoky sooty Union Station. Grimy and worn it is, like some ancient temple in a holy city of India, crowded with listless men, with tired women and crying babies, and bundles, bundles, bundles.

"For 25 years I, too, have gone in and out of that station; yet always that listless, forlorn army is waiting there, waiting for the day coaches to back in, so it can go home to Moberly, or Joplin, or Sedalia; to go home, so it can rest up, save money, and bring more babies back to St. Louis, to spend its money there and wait again for the day coaches to back in, to ride home again.

"From this dark, cavernous maelstrom of men and women, of din and mingled odors, more narrow, cobbly streets lead off, jammed with clanging street-cars, bouncing motors, and jolting trucks—lead off to Olive Street, to Delmar, to King's Highway, to the greater, better, real St. Louis, the mightiest city west of the Mississippi."

The re-routing and improvements recommended by the Committee will eliminate most of the objections referred to previously. As the Union Station is about a mile from the business district, as St. Louis transit lines are so spread out, as it will be many years before any considerable rapid transit can be provided by subways and elevated lines, and as the railroad lines now serve the outlying city and suburban areas, the Committee has recommended that a suburban railroad service be created in connection with a suburban station located near the heart of the down-town business district. The Committee's recommendation on this is as follows:

"As the steam roads own rights-of-way of adequate width to accommodate the additional tracks that would be required for an intensive suburban service, as those tracks can be provided at a very small fraction of the cost of providing rapid transit subways and elevated lines, and as the railroads already have a good foundation in equipment, facilities and organization to furnish such service, with comparatively little extra investment, it seems logical to conclude that the cheapest rapid transit that can be secured within a reasonable time is by an intensive development of the steam lines for suburban service. The only large fixed investment that would be required in the beginning would consist of a downtown suburban station."

Re-routing Passenger Trains

No change was recommended in the re-routing of passenger trains of the Western lines. Of the passenger trains of the Eastern lines about 100 cross the Eads Bridge and 50 cross the Merchants Bridge each day. Those that cross the Merchants Bridge traverse, for 3½ miles, along and across city streets at grade, where automobiles have rights over passenger trains, a very congested and solidly built industrial freight-house district where passenger trains interfere seriously with and are seriously delayed by the handling of freight in that district. In fact, during several hours of the day the movement of freight engines in this district must practically stop in order to permit the operation of scheduled passenger trains. Moreover, the handling of 50 passenger trains per day across the Merchants Bridge seriously interferes with freight operations. This bridge has sufficient carrying capacity for the heaviest railroad equipment.

The 100 passenger trains that use the Eads Bridge are subject to the disability of the St. Louis Tunnel which is about a mile long. Because of the fact that St. Louis locomotives use the soft coal of Southern Illinois, the gases in the tunnel are very objectionable and it is almost impossible to keep them out of passenger cars. Several railroad companies detour passenger trains many miles to the Merchants Bridge in order to avoid the tunnel. The Eads Bridge will not carry the heaviest present-day engines, nor will the tunnel clear the largest equipment.

The Engineers' Committee decided that all passenger trains, except three that circle St. Louis, should be removed from the Eads and the Merchants Bridges, re-routed on the east bank of the river and handled across the river on the railroad tracks of the Municipal Bridge. This involves, in the beginning, the construction of a new lateral approach, connecting with the Municipal Bridge near the east bank of the river, swinging around to the north and coming to grade 1½ miles north of the bridge at the point where the east approach of the Eads Bridge now comes to grade.

As the 100 passenger trains now using the Eads Bridge traverse a very congested freight district in East St. Louis where they seriously interfere with the handling of freight, which situation would be made worse by sending 50 more passenger trains through there from the Merchants Bridge, the Committee recommended, as a second step, that the passenger lines be elevated throughout the congested freight districts on the east side, in order to expedite the handling of passenger trains, and by taking them off the surface to permit greater freedom in the handling of freight. This involves also the construction of a new Union Depot in East St. Louis. The entire project of re-routing passenger trains, which the railroad companies are ready to undertake, will cost about $15 000 000.

Figs. 9 and 10 are graphic diagrams showing the routing and density of passenger train movements of all railroads by the present and the proposed routes.

Fig. 11 shows the relative locations of the Eads and Municipal Bridges and also, by dotted lines, additional approaches that will be built either by the City or by the railroad companies.

The relative locations of the Eads and the Municipal Bridges are interesting. The Municipal Bridge and approaches are parallel to the Eads Bridge and its approaches and 1 mile down the river. On the St. Louis side, the tunnel, after turning 90°, extends south from the Eads Bridge to the west end of the Municipal Bridge approach; on the East St. Louis side the proposed lateral approach will extend north from the Municipal Bridge to the east end of the Eads Bridge. These two routes form, therefore, a rough square, bounded on the north by the Eads Bridge, on the east by the proposed approach, on the south by the Municipal Bridge, and on the west by the tunnel. The present Eads Bridge route follows the north and west sides, the proposed Municipal Bridge route follows the east and south sides. The Municipal Bridge approaches will be more favorable than those of the Eads Bridge and the capacity of the new bridge is ample, having been designed for the Cooper E-60 loading, double track.

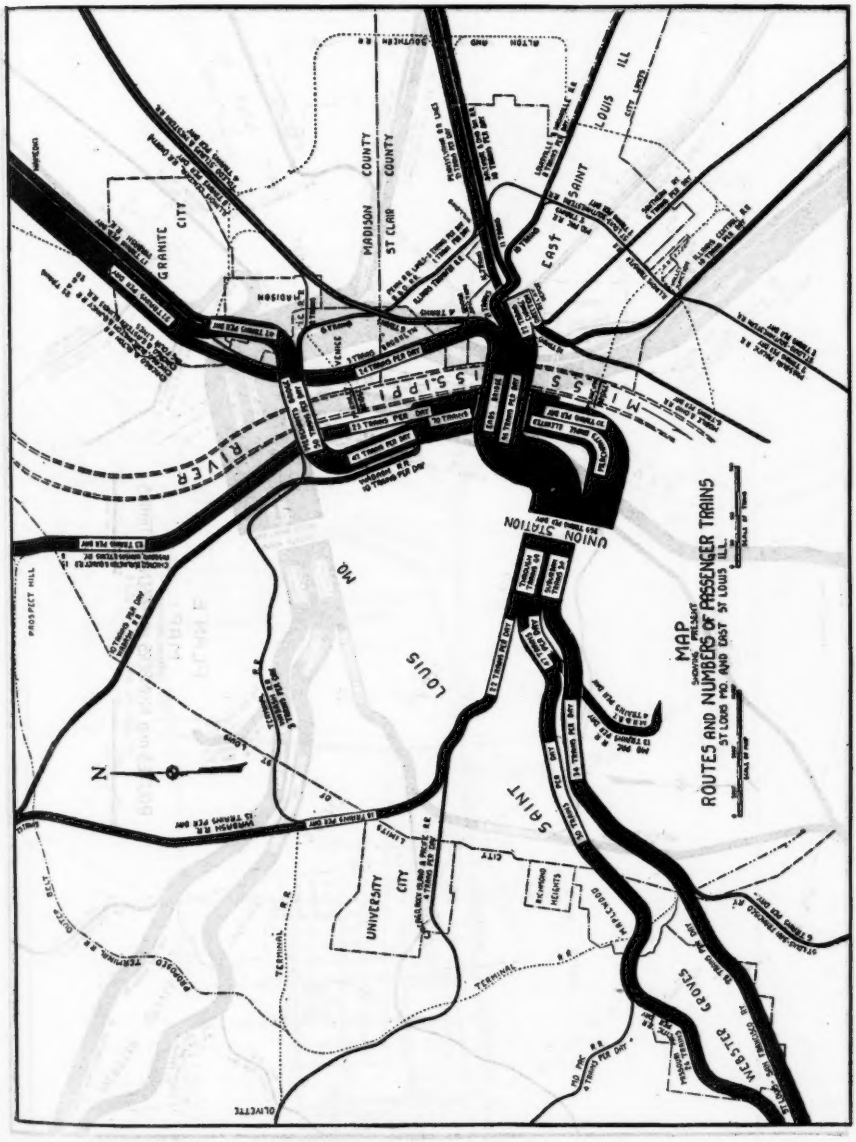

MAP
SHOWING PRESENT
ROUTES AND NUMBERS OF PASSENGER TRAINS
ST LOUIS MO. AND EAST ST LOUIS ILL.
UNION STATION
MISSISSIPPI
RIVER
EAST SAINT LOUIS ILL
GRANITE CITY
MADISON COUNTY
ST CLAIR COUNTY
SAINT LOUIS MO
UNIVERSITY CITY
WEBSTER GROVES
PROSPECT HILL
OLIVETTE
TERMINAL
N

FIG. 9.

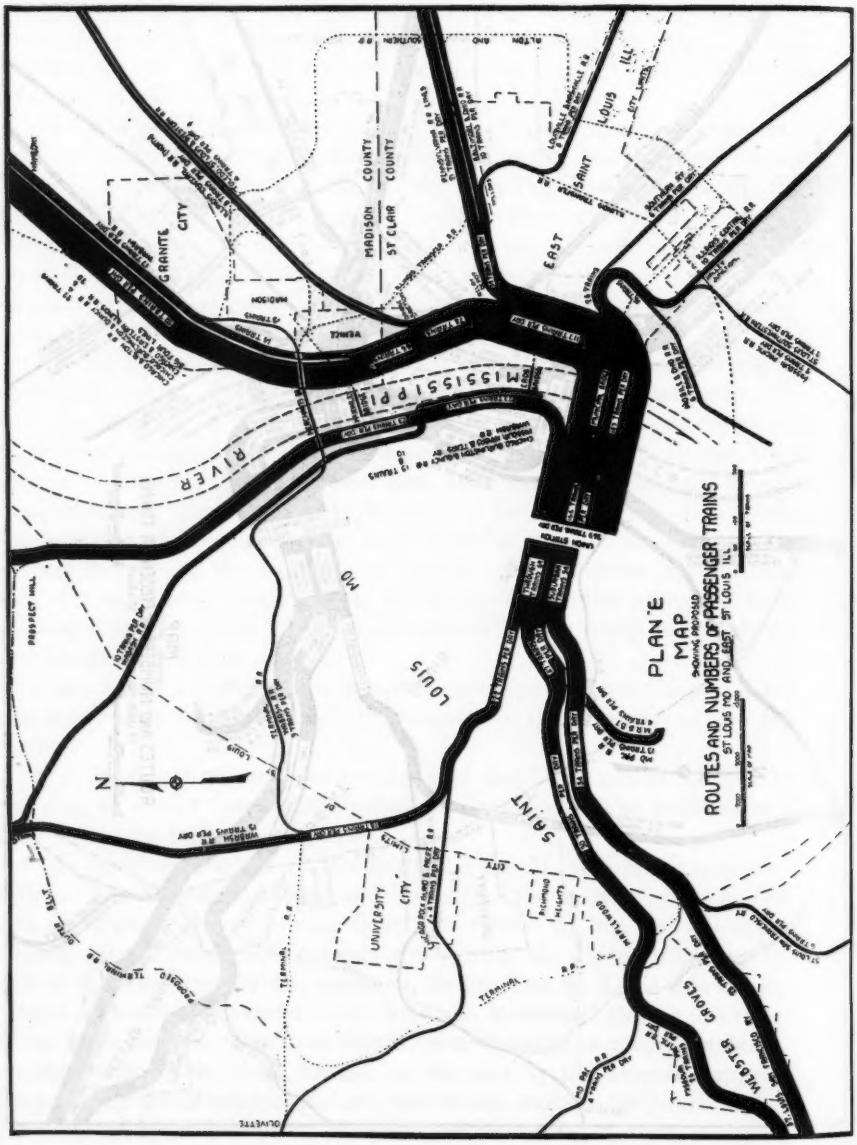

PLAN & MAP
SHOWING PROPOSED
ROUTES AND NUMBERS OF PASSENGER TRAINS
ST. LOUIS MO AND EAST ST LOUIS ILL
MISSISSIPPI RIVER
MADISON COUNTY
ST CLAIR COUNTY
GRANITE CITY
EAST ST LOUIS ILL
MO
ST LOUIS
UNIVERSITY CITY
WEBSTER GROVES
N

FIG. 10.

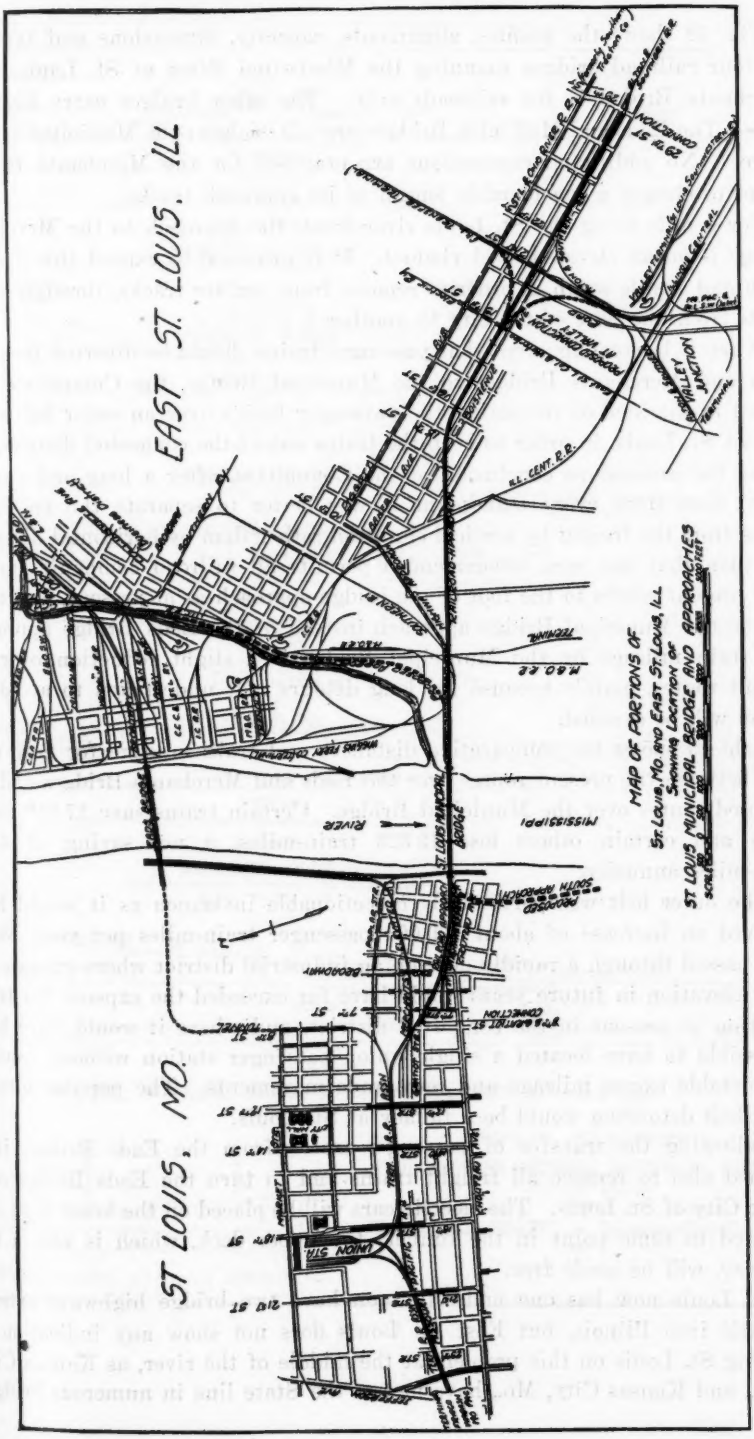

EAST ST. LOUIS, ILL
ST LOUIS, MO.
MAP OF PORTIONS OF
St. Louis, Mo. and East St. Louis, Ill.
Showing Location of
ST LOUIS MUNICIPAL BRIDGE AND APPROACHES
RIVER
MISSISSIPPI
TERMINAL
UNION STA
MERCHANTS BRIDGE TERMINAL RY.
ILL. CENT. R.R.
TERMINAL VALLEY JUNCTION
29TH ST CONNECTION
MADISON
BROADWAY
21ST ST
18TH ST
14TH ST
12TH ST
7TH ST
3RD ST
MARKET ST
CHESTNUT ST
WASHINGTON AVE
PROPOSED SOUTH APPROACH
PROPOSED NORTH APPROACH
7TH & EASTON ST CONNECTION
MISSOURI PACIFIC R.R.
TERMINAL R.R. ASSOC.
WABASH R.R.
TERMINAL
M & O R.R.
TERMINAL
CHICAGO & ALTON R.R.
TERMINAL
TERMINAL R.R. ASSOC.
TERMINAL
ST. LOUIS TERMINAL
TERMINAL
TERMINAL R.R. ASSOC.
TERMINAL
TERMINAL R.R. ASSOC.
TERMINAL
TERMINAL R.R. ASSOC.

Fig. 12 shows the profiles, alignments, capacity, dimensions and types of the four railroad bridges spanning the Mississippi River at St. Louis. The Merchants Bridge is for railroads only. The other bridges carry highway floors. The Eads and McKinley Bridges are toll bridges; the Municipal Bridge is free. No additional connections are proposed for the Merchants Bridge, except to elevate a considerable length of its approach tracks.

For a mile along the St. Louis river-front, the approach to the Merchants Bridge is on an elevated steel viaduct. It is proposed to extend this 2 miles north and 1 mile south in order to remove from surface tracks, through movements from one part of the city to another.

When it became apparent that passenger trains should be diverted from the Eads and Merchants Bridges to the Municipal Bridge, the Committee first turned to the idea of re-routing the passenger trains over an outer belt route in East St. Louis, in order to keep the trains out of the congested district, but it was the unanimous conclusion of the Committee, after a long and careful study, that from every standpoint it was better to separate the passenger trains from the freight by vertical elevation rather than by horizontal distance. The plan that has been recommended permits all railroad companies to use their present routes to the foot of the bridge approach as at present, and there to take the Municipal Bridge approach instead of the Eads Bridge approach. The train mileage by the Municipal Bridge is a slight reduction over the present routes, mainly because the long detours now undertaken to avoid the tunnel will be avoided.

Table 5 shows the comparative distances and train mileage for each railroad between the present routes over the Eads and Merchants Bridges and the proposed routes over the Municipal Bridge. Certain trains save 17 059 train-miles and certain others lose 13 323 train-miles, a net saving of 3 736 train-miles annually.

The outer belt was particularly objectionable inasmuch as it would have involved an increase of about 100 000 passenger train-miles per year, would have passed through a rapidly developing industrial district where expense for track elevation in future years would have far exceeded the expense for track elevation at present in the congested district, and where it would have been impossible to have located a single union passenger station without causing considerable excess mileage and retrograde movements. The popular idea of outer belt detouring would be a fallacy at St. Louis.

Following the transfer of passenger trains from the Eads Bridge, it is planned also to remove all freight trains and to turn the Eads Bridge over to the City of St. Louis. The electric cars will be placed on the lower deck and operated to some point in the tunnel; the upper deck, which is now a toll highway, will be made free.

St. Louis now has one and will soon have two bridge highways extending well into Illinois, but East St. Louis does not show any indication of meeting St. Louis on this problem at the middle of the river, as Kansas City, Kans., and Kansas City, Mo., have met at the State line in numerous bridges.

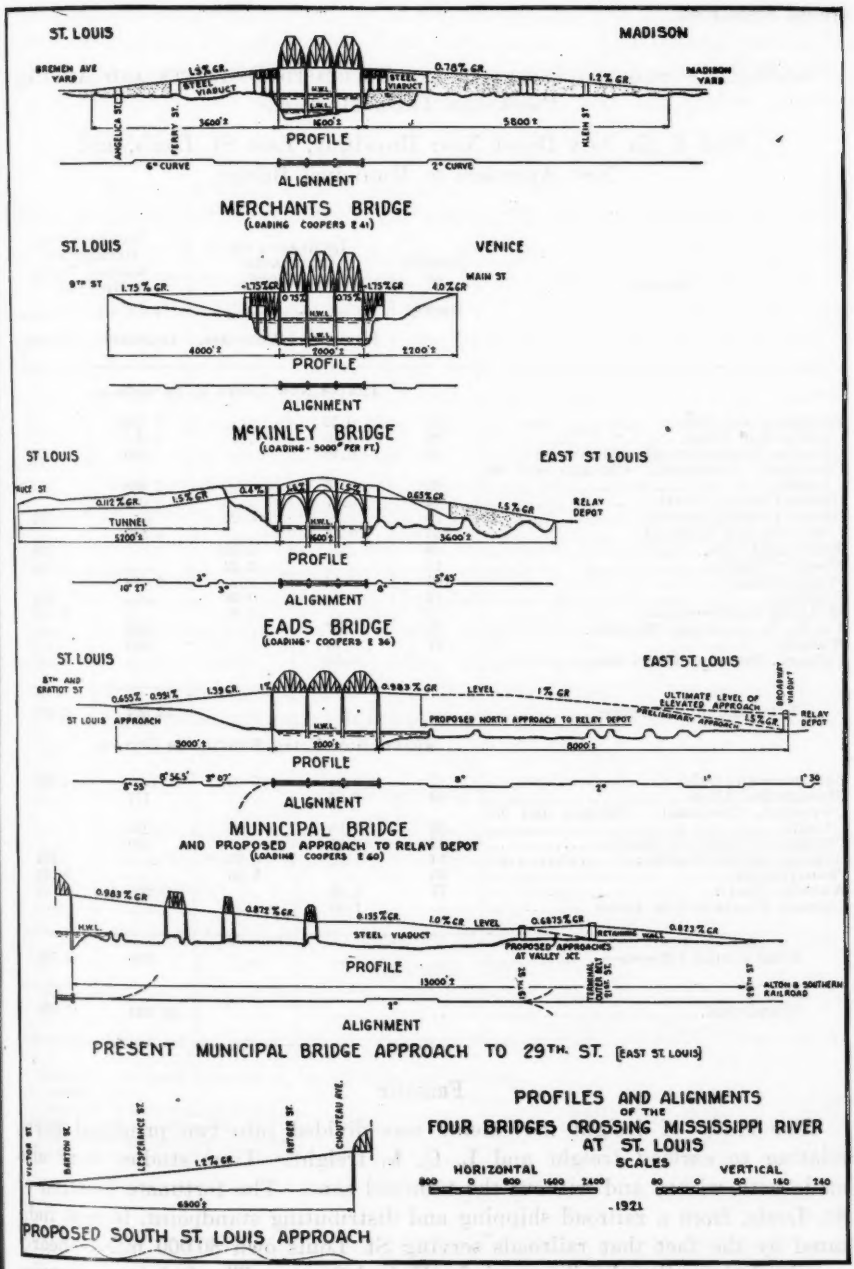

ST. LOUIS
MADISON
BREMEN AVE YARD
STEEL VIADUCT
STEEL VIADUCT
MADISON YARD
ANGELICA ST.
FERRY ST.
KLEIN ST.
PROFILE
6° CURVE
2° CURVE
ALIGNMENT
MERCHANTS BRIDGE
(LOADING COOPERS E 41)
ST. LOUIS
VENICE
MAIN ST
PROFILE
ALIGNMENT
McKINLEY BRIDGE
(LOADING - 3000# PER FT.)
ST LOUIS
EAST ST LOUIS
TUNNEL
RELAY DEPOT
PROFILE
ALIGNMENT
EADS BRIDGE
(LOADING - COOPERS E 36)
ST. LOUIS
EAST ST LOUIS
ST LOUIS APPROACH
PROPOSED NORTH APPROACH TO RELAY DEPOT
RELAY DEPOT
PROFILE
ALIGNMENT
MUNICIPAL BRIDGE
AND PROPOSED APPROACH TO RELAY DEPOT
(LOADING COOPERS E 40)
H.W.L.
STEEL VIADUCT
PROPOSED APPROACHES AT VALLEY JCT.
PROFILE
ALIGNMENT
PRESENT MUNICIPAL BRIDGE APPROACH TO 29TH. ST. (EAST ST. LOUIS)
VICTOR ST.
BARTON ST.
LESPERANCE ST.
RUTGER ST.
CHOUTEAU AVE.
PROPOSED SOUTH ST. LOUIS APPROACH
PROFILES AND ALIGNMENTS
OF THE
FOUR BRIDGES CROSSING MISSISSIPPI RIVER
AT ST. LOUIS
SCALES
HORIZONTAL
VERTICAL
1921

FIG. 12.

This may be adjusted in later years when East St. Louis is larger and has more resources.

TABLE 5.—SHOWING INCREASED AND DECREASED DISTANCES AND ANNUAL PASSENGER TRAIN MILEAGE.

Plan E *via* New Depot Near Broadway, East St. Louis, and New Approach to Municipal Bridge.

Roads.	Number of trains weekly.	INCREASED OR DECREASED DISTANCES.		INCREASED OR DECREASED ANNUAL TRAIN MILEAGE.	
		Increase.	Decrease.	Increase.	Decrease.
TRAINS NOW USING EADS BRIDGE.					
Baltimore and Ohio	61	0.52	....	1 649	....
Chicago and Alton	82	0.46	....	1 961	....
Chicago, Burlington and Quincy	28	0.46	....	670	....
Cleveland, Cincinnati, Chicago and St. Louis	53	0.46	....	1 268	....
Illinois Central (North)	42	0.47	....	1 026	....
Illinois Central (South)	70	....	0.22	....	801
Louisville and Nashville	56	0.53	....	1 543	....
Mobile and Ohio	40	....	0.095	....	198
Missouri Pacific	14	....	2.22	....	1 616
Pennsylvania	109	0.56	....	3 174	....
Southern	42	....	0.28	....	612
St. Louis Southwestern	14	....	2.90	....	2 111
Toledo, St. Louis and Western	28	0.57	....	830	....
Wabash	21	0.46	....	503	....
Chicago, Peoria and St. Louis	..	0.53	....	....	....
Total annual difference	..	....	....	12 624	5 338
TRAINS NOW USING MERCHANTS BRIDGE.					
Baltimore and Ohio	7	....	5.05	....	1 838
Chicago and Alton	68	0.05	....	177	....
Cleveland, Cincinnati, Chicago and St. Louis	82	0.05	....	213	....
Chicago and Eastern Illinois	42	0.05	....	109	....
Illinois Central (North)	14	....	0.95	....	692
Pennsylvania	35	....	5.05	....	9 191
Wabash (East)	77	0.05	....	200	....
Chicago, Peoria and St. Louis	..	1.30	....	....	....
Total annual difference	..	....	....	699	11 721
Grand total	..	....	....	13 323	17 059

FREIGHT

The study of freight movements was divided into two principal parts, relating to carload freight and L. C. L. freight. Time studies were also made both within and without the terminal zone. The fortunate location of St. Louis, from a railroad shipping and distributing standpoint, is well indicated by the fact that railroads serving St. Louis own 80 000 miles—nearly one-third the railroad mileage of the United States. The freight car service that is given by the railroad companies insures one-day delivery as far north as Chicago, east to Cincinnati, south to Nashville, and west to Kansas City; two-

day service north to St. Paul and Lake Ports, east to Pittsburgh, south to Mobile and Shreveport, and west to Oklahoma City and Sioux City; three-day service north to Duluth, east to New York, south to New Orleans and all Gulf Ports, and west to Dallas and Denver; four-day service north to Bismarck, N. Dak., and Montreal; east to Boston and Atlantic Ports, and west to Cheyenne; five-day service north to Canadian border out to Winnipeg, south to the Mexican border, and west to El Paso and Helena, as shown in Fig. 13.

On the other hand, and in comparison with these time figures, the unfortunate conditions in the St. Louis terminal district were made apparent by the time study which indicated that after omitting 10% of the cars which fell by the wayside for one reason or another, the 90% that did move with some speed consumed an average of three days between railroads on opposite banks of the river, the same as the time between St. Louis and Dallas, and four days between railroads on one bank and industries on the other bank, the same as the time between St. Louis and Boston. Many movements were made in one day. Many also consumed eight or ten days in the terminals. The problem was well stated by one of the members of the Business Men's Committee who asked: "What I want to know is, why, after a car is loaded and sealed at my track and billed out, it is still in the terminals eight and ten days thereafter?" This is the problem the Committee sought to solve.

An effort was first made by questionnaire to obtain information relating to the movement of cars in the District, but it was found that the replies were so discrepant that no use could be made, nor could any conclusions be reached, from them. Consequently, freight record clerks were employed and put to work copying in a uniform manner from the records of the railroad companies all necessary information relating to the movements of carload freight.

Carload Freight

Table 6 shows the number of carloads of freight handled in October, 1920, and Table 7 shows the number of loaded and empty freight cars crossing the river that month.

TABLE 6.—Showing Number of Carloads of Freight Handled in October, 1920.

	East Side.	West Side.	Total.
Through carloads brought in by all lines for through movement	60 201	20 030	80 231
Cars loaded at freight-houses	6 060	10 724	16 784
Cars loaded at industries and team tracks	15 356	12 827	28 183
Cars unloaded at freight-houses	5 723	5 823	11 546
Cars unloaded at industries and team tracks	22 838	30 970	53 808
	110 178	80 374	190 552

Fig. 14 shows the amount and distribution throughout the district of carload freight in October, 1920. It was found that the trains were made up and broken up in more than forty individual classification yards, that cars

Number of Days required to make delivery of Merchandise from St. Louis to Principal Cities
1
2
3
4
5
6
7
8
9
10
ST. LOUIS
Quebec
Montreal
Ottawa
Winnipeg
Duluth
Minneapolis
St. Paul
Toronto
Buffalo
Albany
Boston
Portland
Detroit
Cleveland
Pittsburg
Philadelphia
Baltimore
Washington
Norfolk
Richmond
Wilmington
Charleston
Columbia
Savannah
Jacksonville
Tampa
Brunswick
Tallahassee
Pensacola
New Orleans
Mobile
Montgomery
Atlanta
Birmingham
Chattanooga
Nashville
Memphis
Louisville
Cincinnati
Columbus
Indianapolis
Chicago
Milwaukee
Madison
Lansing
Toledo
Frankfort
Vincennes
Springfield
Peoria
Cairo
Jefferson City
Kansas City
Omaha
Sioux City
Des Moines
Topeka
Wichita
Lincoln
Bismarck
Pierre
Helena
Cheyenne
Denver
Pueblo
Salt Lake City
Santa Fe
El Paso
Phoenix
Spokane
Seattle
Portland
Boise
Carson City
Sacramento
San Francisco
Los Angeles
Tahlequah
Little Rock
Texarkana
Shreveport
Batch Rouge
Houston
Galveston
Dallas
Denison
Waco
Austin
Ft. Worth
San Antonio
Laredo
Oklahoma City
Guthrie
Tulsa
Jackson
Augusta
Charleston
Raleigh
Harrisburg
Hartford
Providence
Boston
Concord
Montpelier
Portland
Albany
New York
Trenton
Baltimore
Dover
Norfolk
Richmond
Washington
Wilmington
Columbia
Charleston
Savannah
Jacksonville
Tampa
Brunswick
Tallahassee
Pensacola
New Orleans
Mobile
Montgomery
Atlanta
Birmingham
Chattanooga
Nashville
Memphis
Louisville
Cincinnati
Columbus
Indianapolis
Chicago
Milwaukee
Madison
Lansing
Toledo
Frankfort
Vincennes
Springfield
Peoria
Cairo
Jefferson City
Kansas City
Omaha
Sioux City
Des Moines
Topeka
Wichita
Lincoln
Bismarck
Pierre
Helena
Cheyenne
Denver
Pueblo
Salt Lake City
Santa Fe
El Paso
Phoenix
Spokane
Seattle
Portland
Boise
Carson City
Sacramento
San Francisco
Los Angeles
Tahlequah
Little Rock
Texarkana
Shreveport
Batch Rouge
Houston
Galveston
Dallas
Denison
Waco
Austin
Ft. Worth
San Antonio
Laredo
Oklahoma City
Guthrie
Tulsa
Jackson
Augusta
Charleston
Raleigh
Harrisburg
Hartford
Providence
Boston
Concord
Montpelier
Portland
MAINE
VT.
N. H.
MASS.
CONN.
R. I.
N. J.
N. Y.
PENNSYLVANIA
OHIO
W. VA.
VIRGINIA
NORTH CAROLINA
SOUTH CAR.
GEORGIA
FLORIDA
KENTUCKY
TENNESSEE
MISS.
ALABAMA
INDIANA
ILLINOIS
MISSOURI
ARKANSAS
LA.
OKLA.
TEXAS
KANSAS
NEBRASKA
IOWA
MINN.
WISCONSIN
MICHIGAN
NORTH DAKOTA
SOUTH DAKOTA
WYOMING
COLORADO
NEW MEXICO
ARIZONA
UTAH
NEVADA
IDAHO
MONTANA
OREGON
CALIFORNIA
WASH.
GULF OF MEXICO
PACIFIC OCEAN

FIG. 13.

passing between railroads were interchanged at more than one hundred interchange points (Fig. 15), that in this service cars were sometimes classified three or four times in one day, transported over devious routes, back-hauled and generally subjected to a tremendous amount of unnecessary handling involving delay and expense. In this service, locomotives moved many miles without cars.

TABLE 7.—SHOWING NUMBER OF LOADED AND EMPTY FREIGHT CARS CROSSING MISSISSIPPI RIVER AT ST. LOUIS, BASED ON OCTOBER, 1920, BUSINESS.*

	Carloads.	Empty cars.
Eastbound	41 584	31 832
Westbound	51 032	20 828
Total	92 616	52 660

* Grand total loaded and empty cars crossing river, 145 276.

A very considerable amount of the delay and expense was due to the fact that all the railroad companies, except a few that have provided outer yards, and a considerable part of the freight of those that have provided outer yards, is handled in the congested districts, whereas only a small proportion of the cars should be handled there. With the information thus obtained, flow diagrams were prepared, showing the density and routing of carload movements of each individual railroad in the district, showing also the yards in which cars were switched, points of interchange with other railroads, etc. These diagrams answered all questions. The answer to the business man's question can be stated in a few words—unnecessary switching and movement of freight cars by reason of each railroad company conducting its own classification yards and interchange points. In the preparation of these diagrams, the movements of about 250 000 freight cars during October, 1920, were studied and recorded. Attention was also given to the cars handled across the river *via* the Alton Bridge, 20 miles above the city, the Missouri Pacific Ferry below the city, and the McKinley Bridge, an interurban electric bridge within the city, as well as the heavy movements across the Eads and Merchants Bridges.

Figs. 16 to 28 show the loaded freight-car movements of each railroad during October, 1920. Even a casual study of these diagrams will show what is the matter with the terminals. Fig. 28 is a composite diagram of the movement of all empty cars.

Table 8 was prepared to show the proportion of cars handled by each railroad company local to its own terminal and in connection with other railroads. The study indicated that of all cars handled in and out of the District by the individual railroads, only 15% were the business of customers located on the individual roads in this district, that is, originated on or were destined for delivery on their lines within the terminals, and that 85% were for interchange with other railroads, either for handling within the District by those railroads, or

for through movement. It was not difficult for the Committee to conclude that the 85% that had no business in the down-town terminals should be kept out to the mutual good of the 85% of interchange business and the 15% of local business which could then be given better service in the congested districts free from unnecessary traffic. Of course, this could have been effected by the provision of outer yards by each railroad company, but the Committee concluded that the situation could be corrected only partly by each railroad

FIG. 14.

company providing its own outer yards, for the reason that each railroad company would still be engaged in the business of classifying and delivering cars to other railroads, whereas the consolidation or unification of such business would simplify the work and result in fewer movements and much less handling.

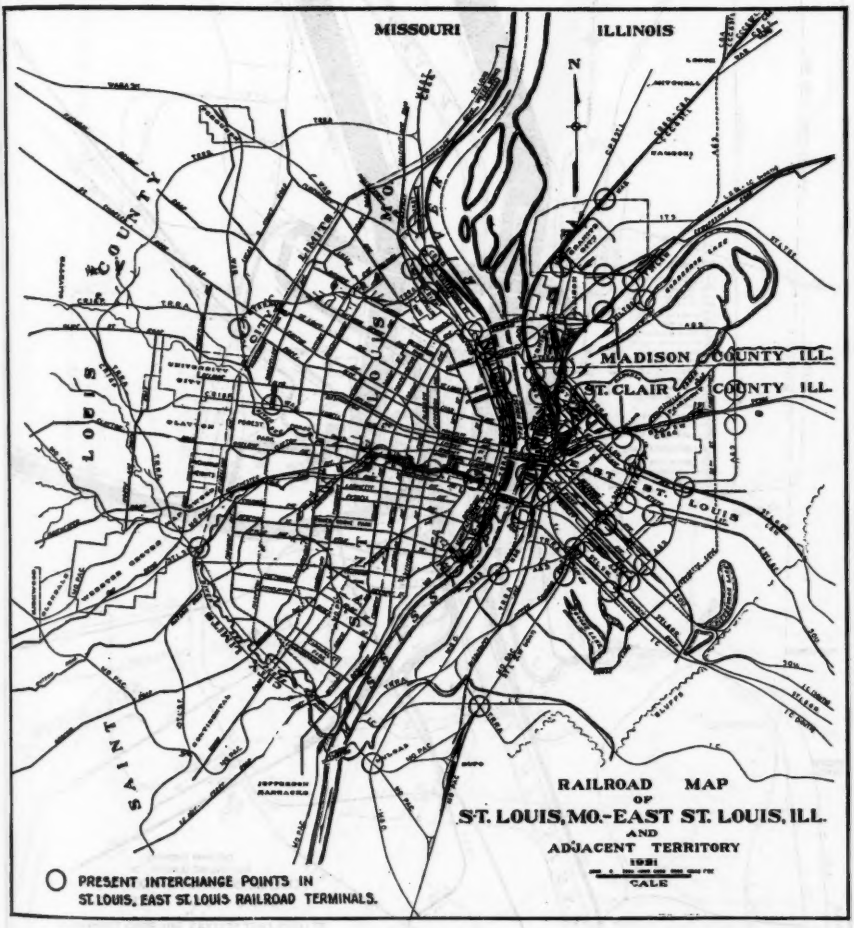

MISSOURI
ILLINOIS
N
MADISON COUNTY ILL.
ST. CLAIR COUNTY ILL.
EAST ST. LOUIS
RAILROAD MAP
OF
ST. LOUIS, MO.-EAST ST. LOUIS, ILL.
AND
ADJACENT TERRITORY
1921
SCALE
PRESENT INTERCHANGE POINTS IN
ST. LOUIS, EAST ST. LOUIS RAILROAD TERMINALS.

FIG. 15.

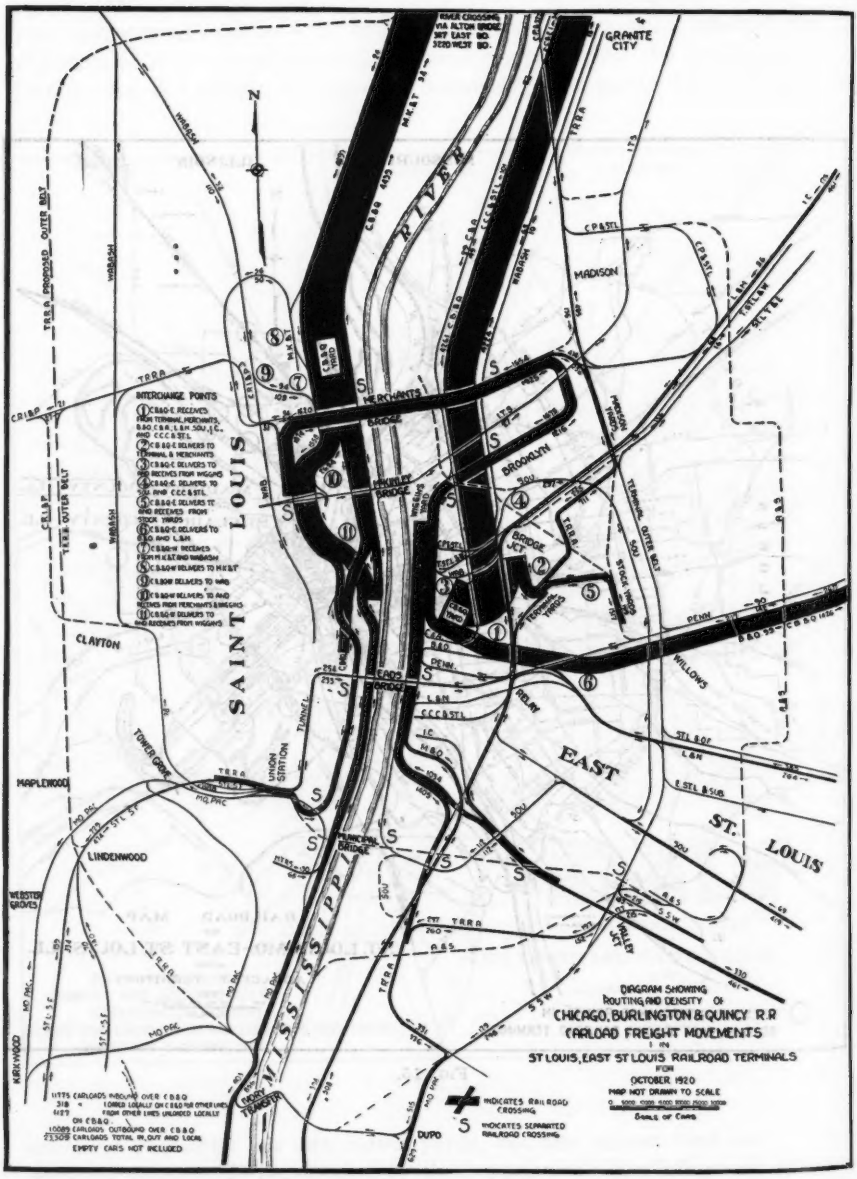

SAINT LOUIS
MISSISSIPPI RIVER
EAST ST. LOUIS
GRANITE CITY
MADISON
BROOKLYN
CLAYTON
MAPLEWOOD
LINDENWOOD
WEBSTER GROVES
KIRKWOOD
DUPO
INTERCHANGE POINTS
DIAGRAM SHOWING ROUTING AND DENSITY OF CHICAGO, BURLINGTON & QUINCY R.R CARLOAD FREIGHT MOVEMENTS IN ST LOUIS, EAST ST LOUIS RAILROAD TERMINALS FOR OCTOBER 1920
MAP NOT DRAWN TO SCALE
INDICATES RAILROAD CROSSING
INDICATES SEPARATED RAILROAD CROSSING
EMPTY CARS NOT INCLUDED

FIG. 16.

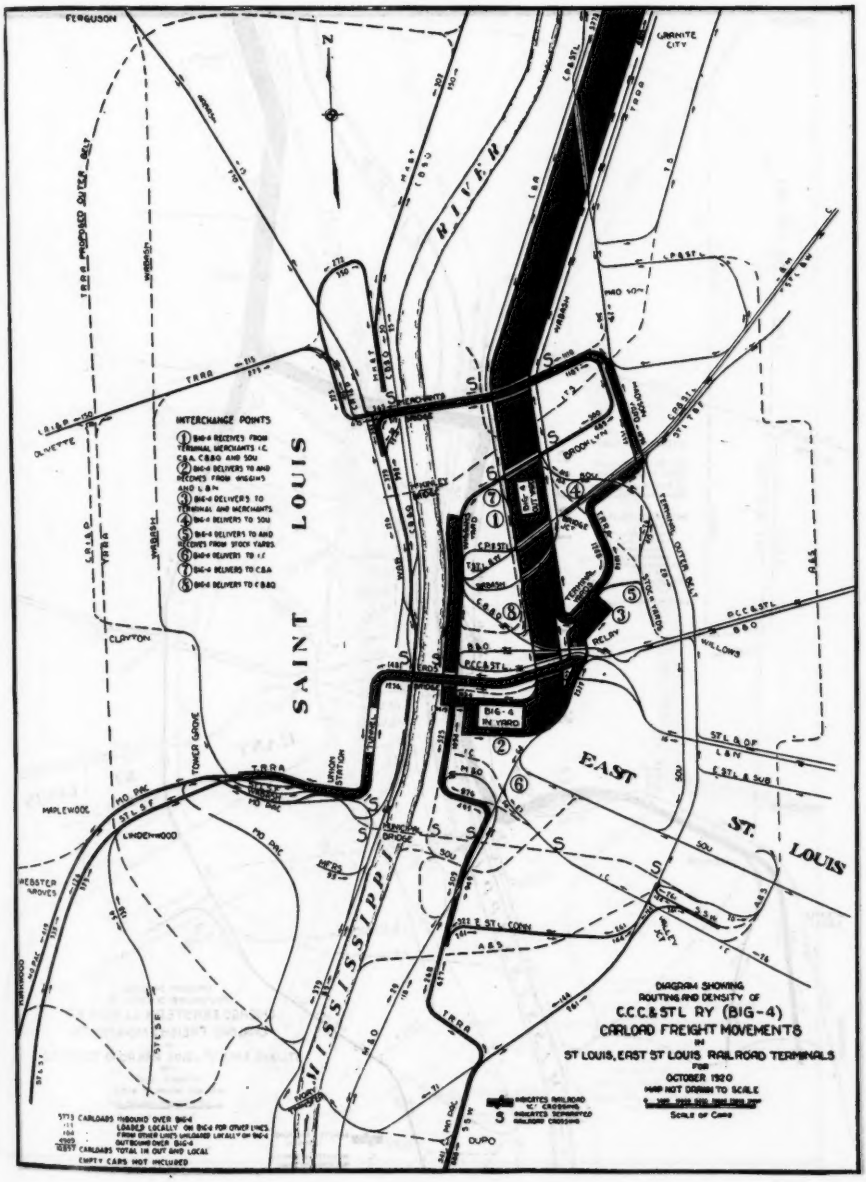

FERGUSON
GRANITE CITY
RIVER
MISSISSIPPI
SAINT LOUIS
EAST ST. LOUIS
CLAYTON
MAPLEWOOD
LINDENWOOD
WEBSTER GROVES
TOWER GROVE
BIG-4 IN YARD
INTERCHANGE POINTS
DIAGRAM SHOWING ROUTING AND DENSITY OF C.C.C.&STL RY (BIG-4) CARLOAD FREIGHT MOVEMENTS IN ST LOUIS, EAST ST LOUIS RAILROAD TERMINALS FOR OCTOBER 1920
MAP NOT DRAWN TO SCALE
DUPO

FIG. 17.

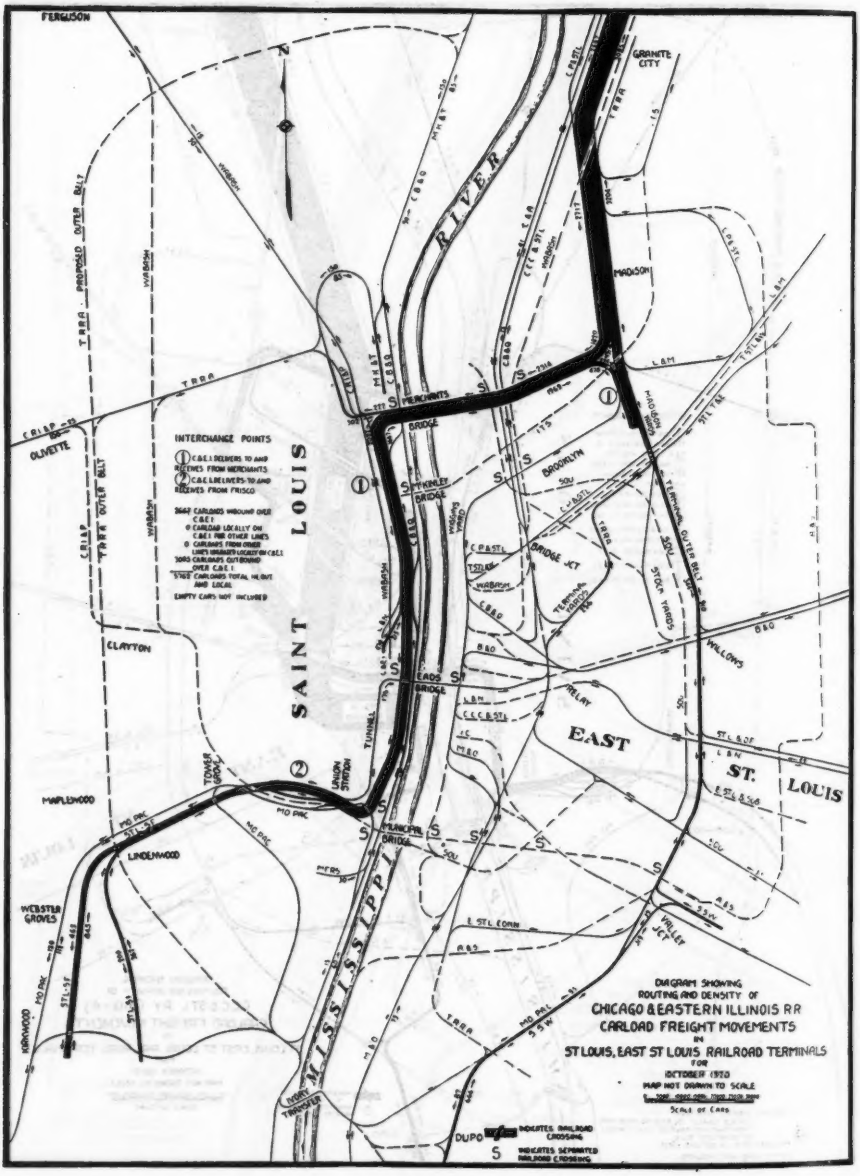

FERGUSON
GRANITE CITY
RIVER
MADISON
OLIVETTE
CLAYTON
MAPLEWOOD
LINDENWOOD
WEBSTER GROVES
KIRKWOOD
ST. LOUIS
EAST ST. LOUIS
MISSISSIPPI
INTERCHANGE POINTS
① C&EI DELIVERS TO AND RECEIVES FROM MERCHANTS
② C&EI DELIVERS TO AND RECEIVES FROM FRISCO
3667 CARLOADS INBOUND OVER C&EI
0 CARLOAD LOCALLY ON C&EI FOR OTHER LINES
0 CARLOADS FROM OTHER LINES INTERCHANGED LOCALLY ON C&EI
3093 CARLOADS OUTBOUND OVER C&EI
3760 CARLOADS TOTAL INBOUND AND LOCAL
EMPTY CARS NOT INCLUDED
DIAGRAM SHOWING ROUTING AND DENSITY OF CHICAGO & EASTERN ILLINOIS RR CARLOAD FREIGHT MOVEMENTS IN ST LOUIS, EAST ST LOUIS RAILROAD TERMINALS FOR OCTOBER 1930
MAP NOT DRAWN TO SCALE
SCALE OF CARS
INDICATES RAILROAD CROSSING
INDICATES SEPARATED RAILROAD CROSSING

FIG. 18.

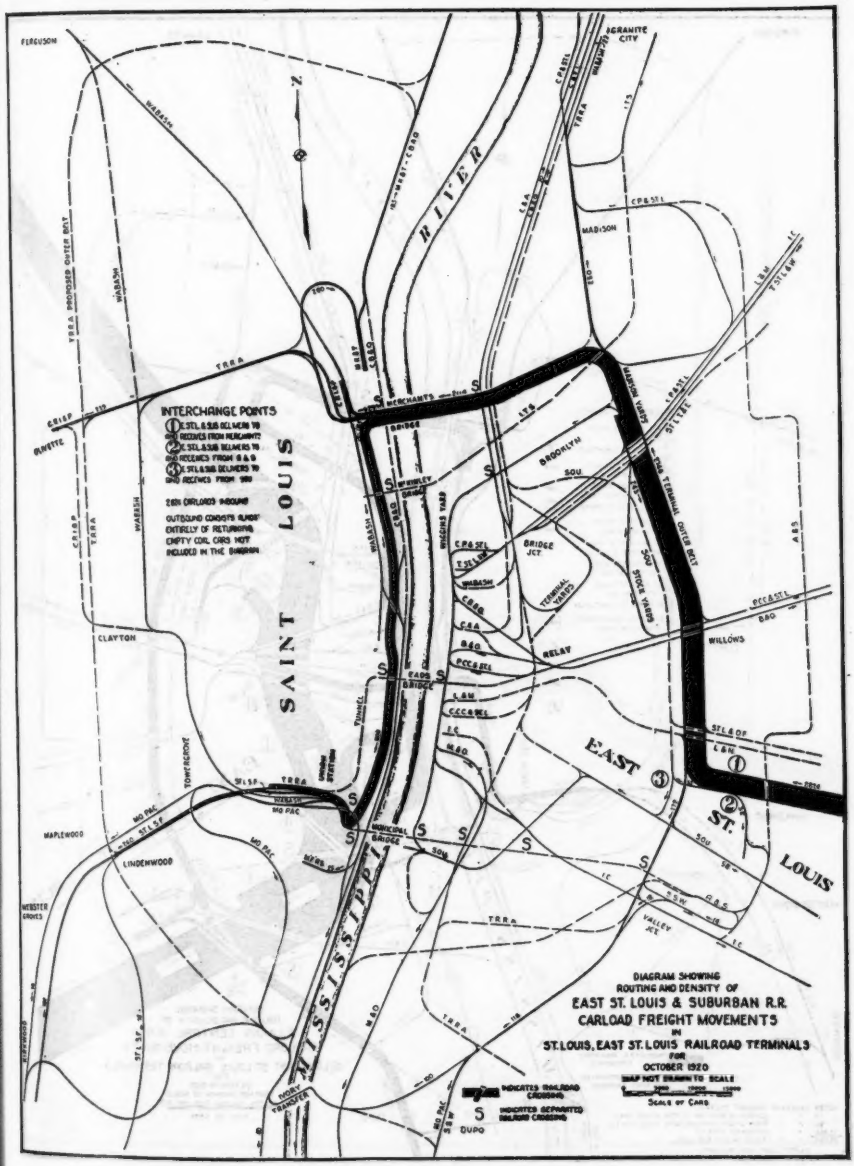

INTERCHANGE POINTS
DIAGRAM SHOWING
ROUTING AND DENSITY OF
EAST ST. LOUIS & SUBURBAN R.R.
CARLOAD FREIGHT MOVEMENTS
IN
ST. LOUIS, EAST ST. LOUIS RAILROAD TERMINALS
FOR
OCTOBER 1920
MAP NOT DRAWN TO SCALE
SCALE OF CARS
INDICATES RAILROAD CROSSING
INDICATES SEPARATED RAILROAD CROSSING
5 DUPO
SAINT LOUIS
EAST ST. LOUIS
MISSISSIPPI RIVER
MERCHANTS BRIDGE
EADS BRIDGE
MacKINLEY BRIDGE
WIGGINS YARD
BRIDGE JCT.
TERMINAL JUNCTION
STOCK YARDS
RELAY
VALLEY JCT.
TERMINAL TRACK
TRRA
WABASH
MO PAC
SOU
CPRR
CRIP
GRANITE CITY
MADISON
BROOKLYN
WILLOWS
CLAYTON
MAPLEWOOD
LINDENWOOD
FERGUSON
WEBSTER GROVES

FIG. 19.

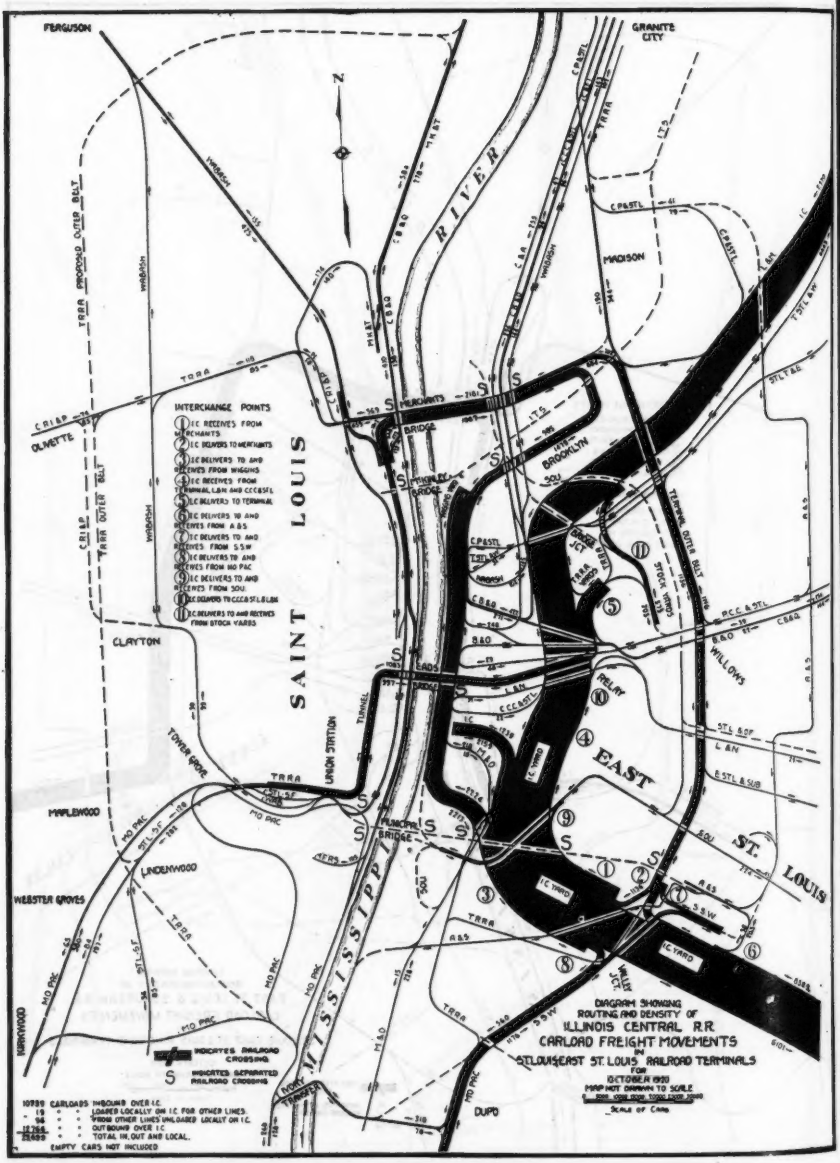

FERGUSON
GRANITE CITY
N
RIVER
MISSISSIPPI
SAINT LOUIS
EAST ST. LOUIS
MADISON
BROOKLYN
CLAYTON
MAPLEWOOD
WEBSTER GROVES
LINDENWOOD
KIRKWOOD
OLIVETTE
INTERCHANGE POINTS
1 IC RECEIVES FROM MERCHANTS
2 IC DELIVERS TO MERCHANTS
3 IC DELIVERS TO AND RECEIVES FROM WIGGINS
4 IC RECEIVES FROM TERMINAL LAIN AND CCC&STL
5 IC DELIVERS TO TERMINAL
6 IC DELIVERS TO AND RECEIVES FROM A&S
7 IC DELIVERS TO AND RECEIVES FROM S.S.W
8 IC DELIVERS TO AND RECEIVES FROM MO PAC
9 IC DELIVERS TO AND RECEIVES FROM SOU.
10 IC BOARDS TO CCC&STL&LAIN
11 IC DELIVERS TO AND RECEIVES FROM STOCK YARDS
INDICATES RAILROAD CROSSING
INDICATES SEPARATED RAILROAD CROSSING
10980 CARLOADS INBOUND OVER I.C.
19 " " LOADED LOCALLY ON I.C. FOR OTHER LINES.
98 " " FROM OTHER LINES UNLOADED LOCALLY ON I.C.
12264 " " OUTBOUND OVER I.C.
23489 " " TOTAL IN, OUT AND LOCAL.
EMPTY CARS NOT INCLUDED
DIAGRAM SHOWING ROUTING AND DENSITY OF ILLINOIS CENTRAL R.R. CARLOAD FREIGHT MOVEMENTS TO ST. LOUIS-EAST ST. LOUIS RAILROAD TERMINALS FOR OCTOBER 1923
MAP NOT DRAWN TO SCALE
SCALE OF CARS
DUPO

FIG. 20.

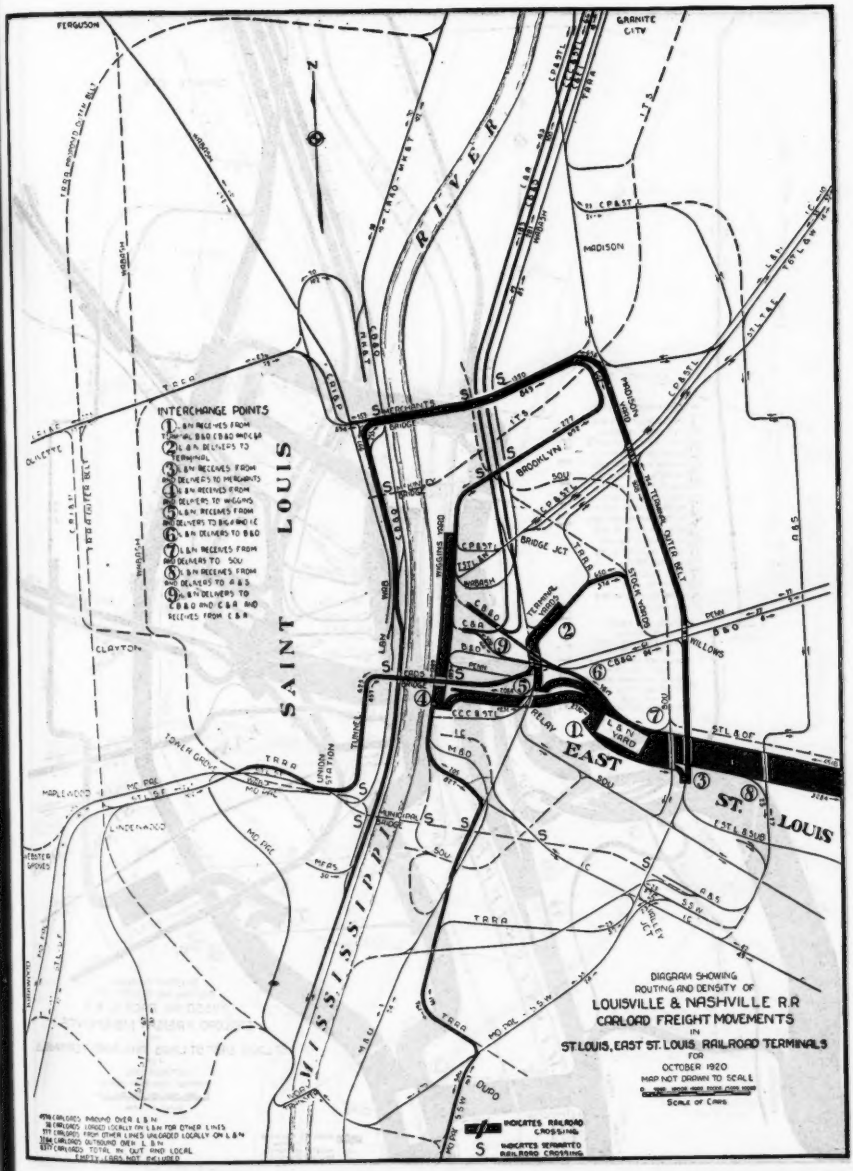

FERGUSON
GRANITE CITY
MADISON
ST. LOUIS
EAST ST. LOUIS
CLAYTON
MAPLEWOOD
LINDENWOOD
WEBSTER GROVES
BROOKLYN
BRIDGE JCT
TERMINAL JUNCTION
RELAY
L & N YARD
MILLERS
STOCK YARDS
MISSISSIPPI
RIVER
INTERCHANGE POINTS
1 L&N RECEIVES FROM TERMINAL B&O C B&O MOE&I
2 L & N DELIVERS TO TERMINAL
3 L&N RECEIVES FROM DELIVERS TO MERCHANTS
4 L & N RECEIVES FROM DELIVERS TO WIGGINS
5 L&N RECEIVES FROM DELIVERS TO B&O AND I C
6 L & N DELIVERS TO B&O
7 L & N RECEIVES FROM DELIVERS TO SOU
8 L & N RECEIVES FROM DELIVERS TO C B & S
9 L & N DELIVERS TO C B & O AND C & A AND RECEIVES FROM C & A
DIAGRAM SHOWING ROUTING AND DENSITY OF LOUISVILLE & NASHVILLE R.R CARLOAD FREIGHT MOVEMENTS IN ST. LOUIS, EAST ST. LOUIS RAILROAD TERMINALS FOR OCTOBER 1920
MAP NOT DRAWN TO SCALE
Scale of Cars
INDICATES RAILROAD CROSSING
INDICATES SEPARATED RAILROAD CROSSING

FIG. 21.

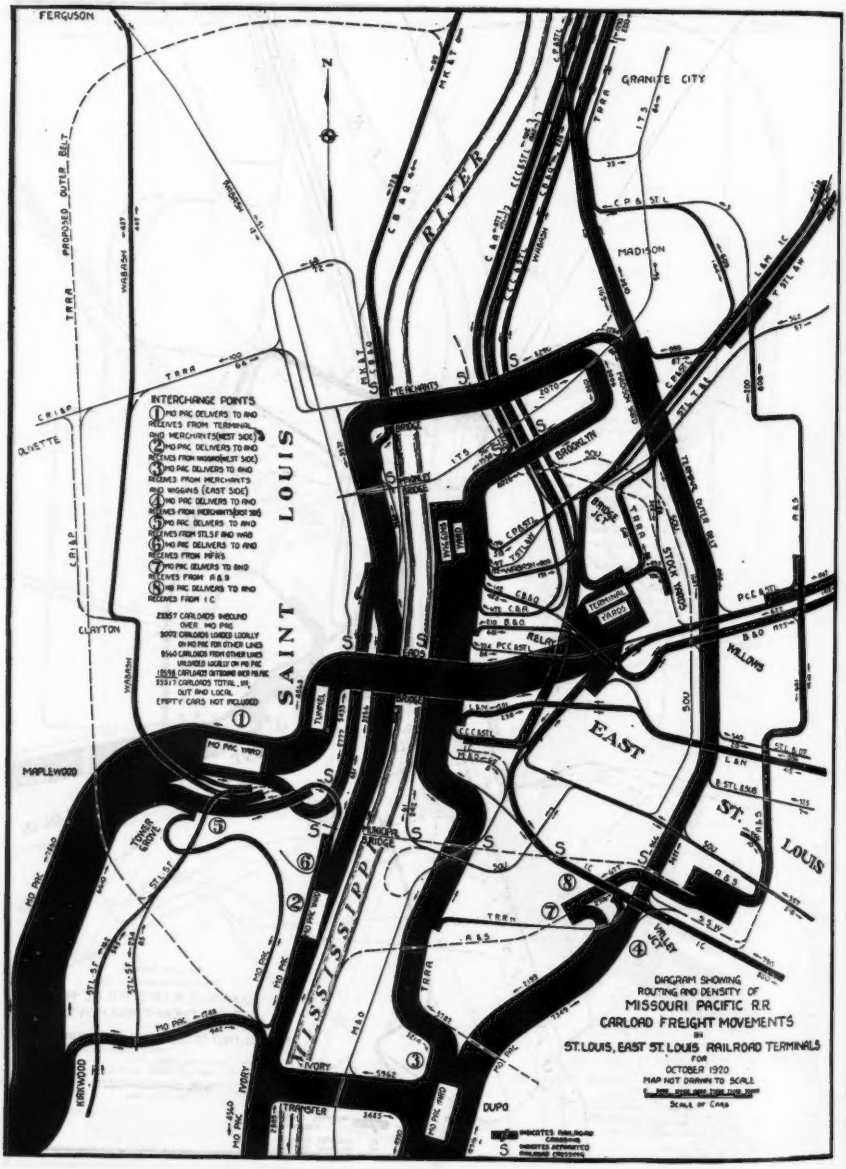

FERGUSON
GRANITE CITY
MADISON
RIVER
SAINT LOUIS
EAST ST. LOUIS
CLAYTON
MAPLEWOOD
OLIVETTE
INTERCHANGE POINTS
DIAGRAM SHOWING ROUTING AND DENSITY OF MISSOURI PACIFIC R.R CARLOAD FREIGHT MOVEMENTS IN ST. LOUIS, EAST ST. LOUIS RAILROAD TERMINALS FOR OCTOBER 1920
MAP NOT DRAWN TO SCALE
Scale of Cars

FIG. 22.

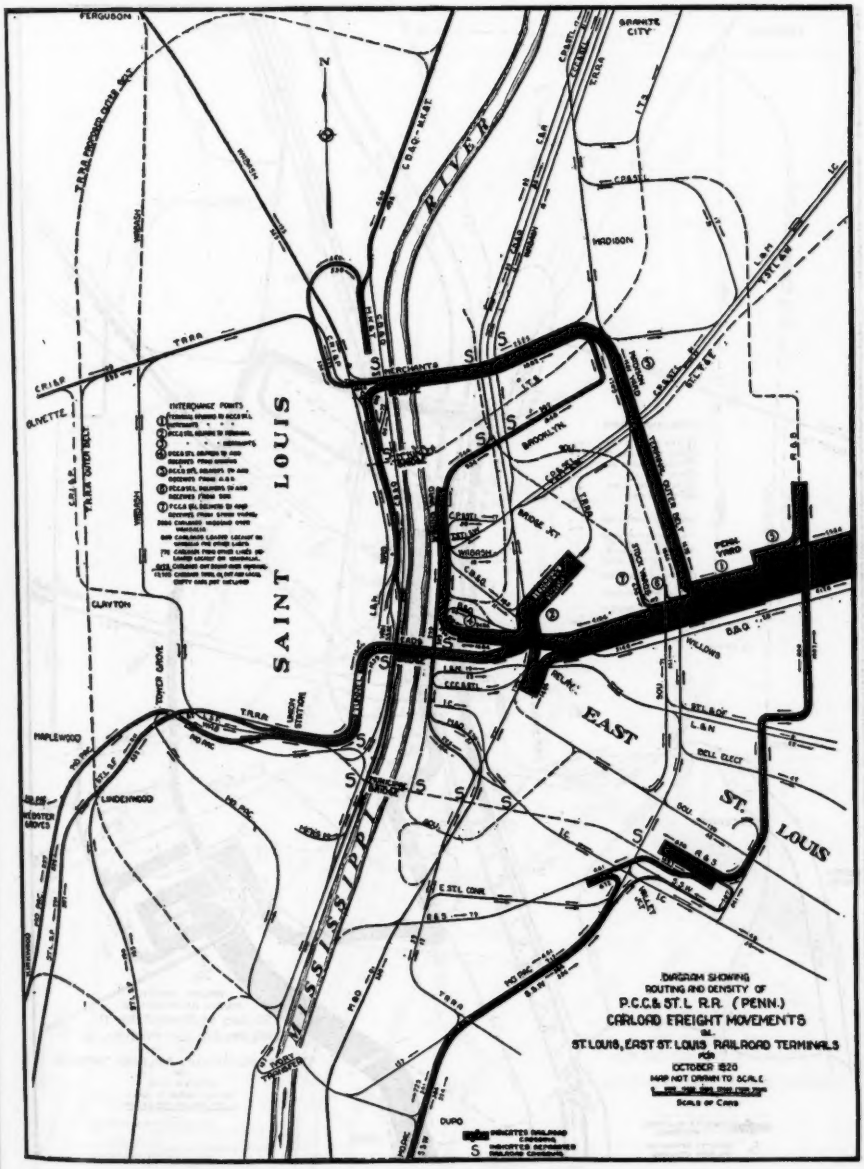

FERGUSON
GRANITE CITY
N
RIVER
MADISON
CRISP
GRANDE GLAISE
CLAYTON
SAINT LOUIS
MAPLEWOOD
LINDENWOOD
WEBSTER GROVES
MISSISSIPPI
EAST ST. LOUIS
DIAGRAM SHOWING
ROUTING AND DENSITY OF
P.C.C.& ST.L. R.R. (PENN.)
CARLOAD FREIGHT MOVEMENTS
at
ST. LOUIS, EAST ST. LOUIS RAILROAD TERMINALS
FOR
OCTOBER 1920
MAP NOT DRAWN TO SCALE
Scale of Cars

FIG. 23.

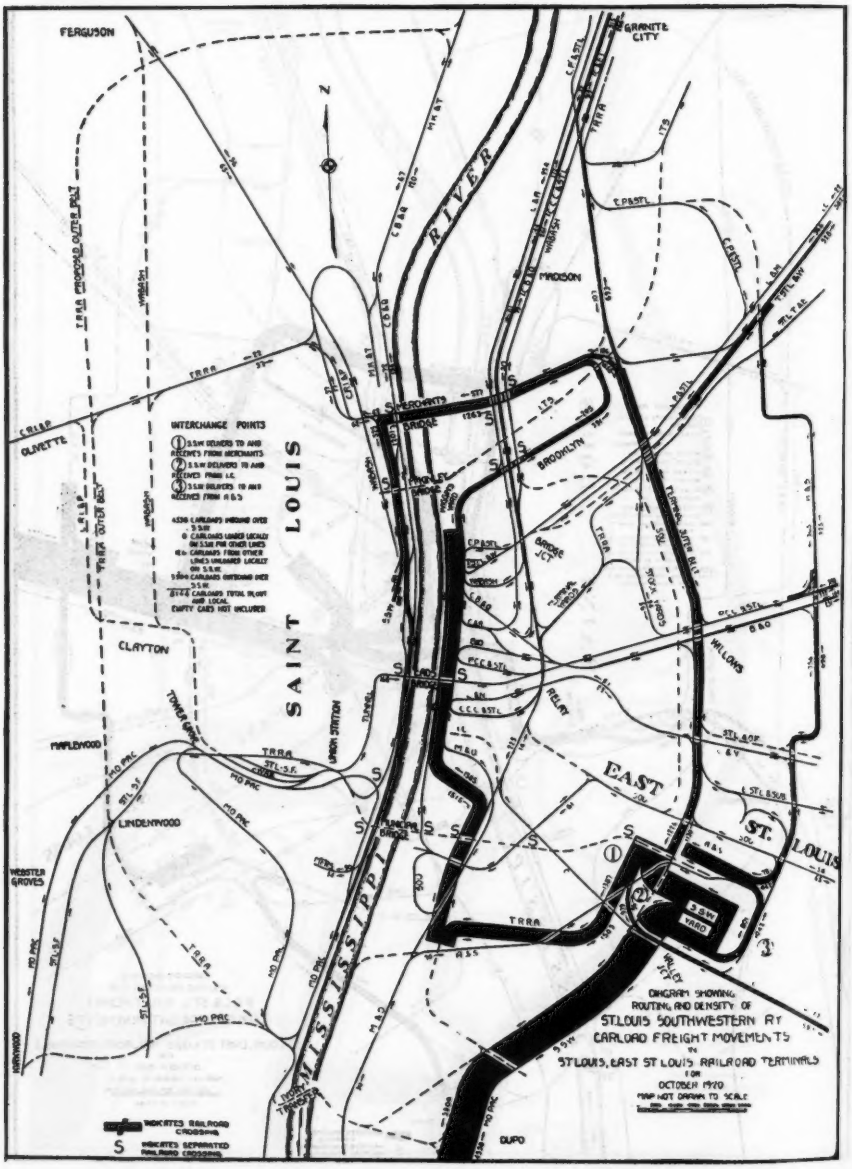

FERGUSON
GRANITE CITY
RIVER
MISSISSIPPI
SAINT LOUIS
EAST ST. LOUIS
CLAYTON
LINDENWOOD
MAPLEWOOD
WEBSTER GROVES
GLENDALE
MADISON
BROOKLYN
MILLS
INTERCHANGE POINTS
DIAGRAM SHOWING ROUTING AND DENSITY OF ST LOUIS SOUTHWESTERN RY CARLOAD FREIGHT MOVEMENTS TO ST LOUIS, EAST ST LOUIS RAILROAD TERMINALS FOR OCTOBER 1920
MAP NOT DRAWN TO SCALE
INDICATES RAILROAD CROSSING
INDICATES SEPARATED RAILROAD CROSSING

FIG. 24.

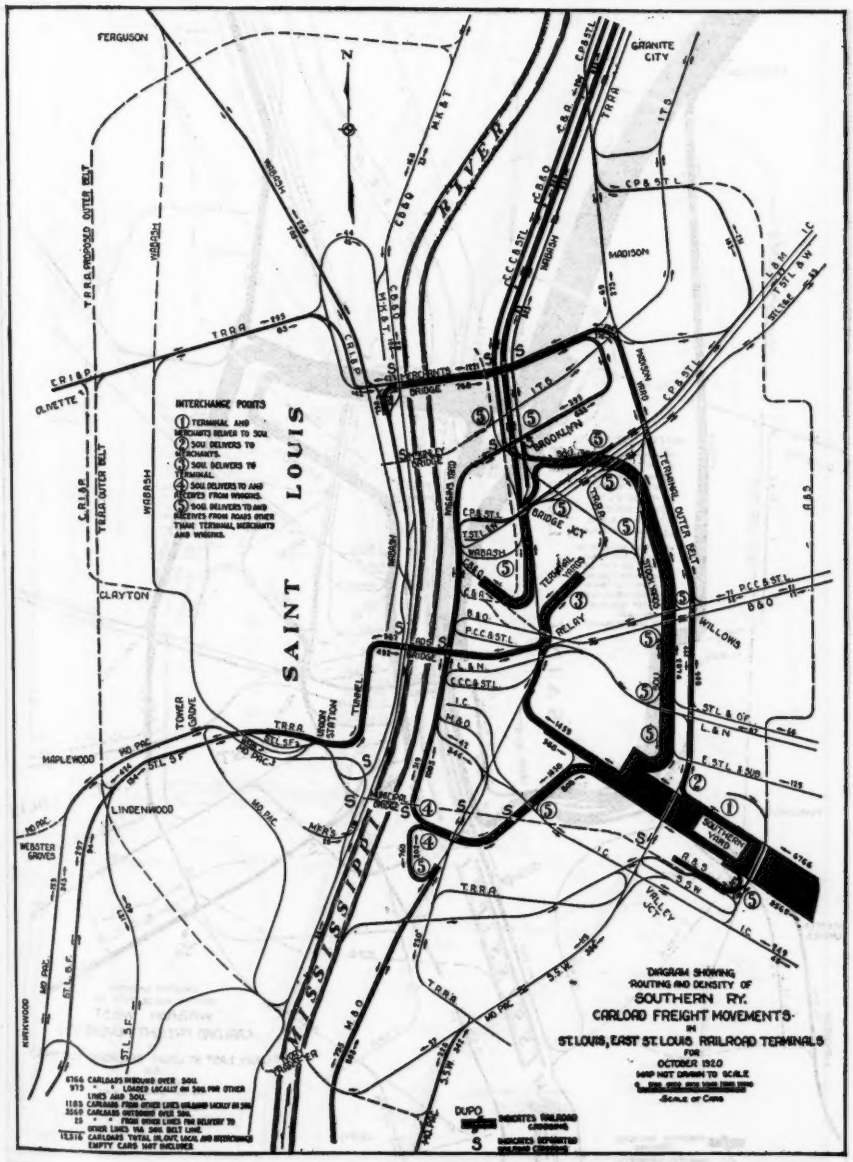

FERGUSON
GRANITE CITY
RIVER
MISSISSIPPI
SAINT LOUIS
CLAYTON
MAPLEWOOD
LINDENWOOD
WEBSTER GROVES
KIRKWOOD
MADISON
BROOKLYN
BRIDGE JCT
RELAY
VALLEY JCT
WILLOWS
TUNNEL
INTERCHANGE POINTS
1 TERMINAL AND MERCHANTS DELIVER TO SOU
2 SOU DELIVERS TO MERCHANTS.
3 SOU DELIVERS TO TERMINAL.
4 SOU DELIVERS TO AND RECEIVES FROM WIGGINS.
5 SOU DELIVERS TO AND RECEIVES FROM ROADS OTHER THAN TERMINAL, MERCHANTS AND WIGGINS.
DIAGRAM SHOWING ROUTING AND DENSITY OF SOUTHERN RY. CARLOAD FREIGHT MOVEMENTS IN ST. LOUIS, EAST ST. LOUIS RAILROAD TERMINALS FOR OCTOBER 1920
MAP NOT DRAWN TO SCALE
SCALE OF CARS
DUPO
INDICATES RAILROAD CROSSING
INDICATES SEPARATED GRADE CROSSING

FIG. 25.

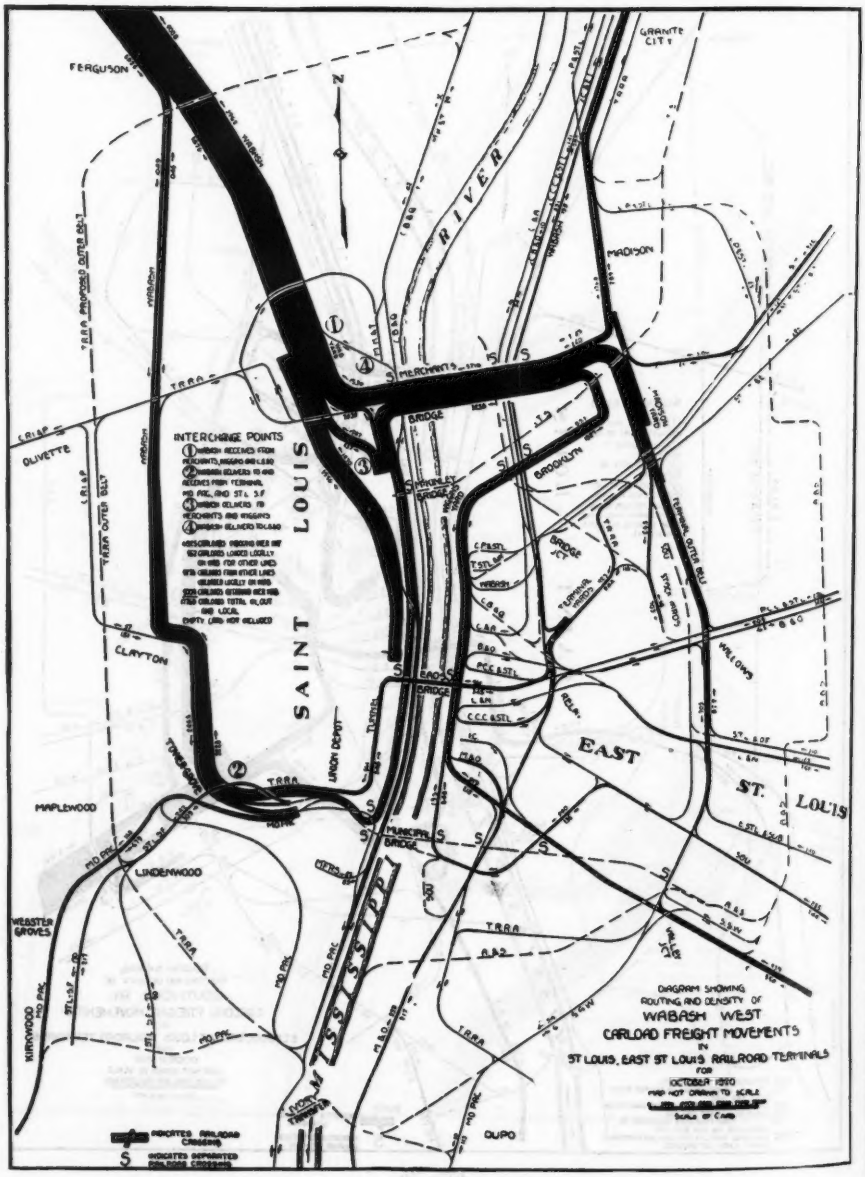

FERGUSON
GRANITE CITY
RIVER
MADISON
MERCHANTS BRIDGE
BRIDGE
McKINLEY BRIDGE
BROOKLYN
OLIVETTE
CLAYTON
SAINT LOUIS
TERMINAL OUTER BELT
WELLS
EAST ST. LOUIS
MAPLEWOOD
LINDENWOOD
WEBSTER GROVES
KIRKWOOD
MISSISSIPPI
DUPO
INTERCHANGE POINTS
DIAGRAM SHOWING
ROUTING AND DENSITY OF
WABASH WEST
CARLOAD FREIGHT MOVEMENTS
IN
ST LOUIS, EAST ST LOUIS RAILROAD TERMINALS
FOR
OCTOBER 1910

FIG. 26.

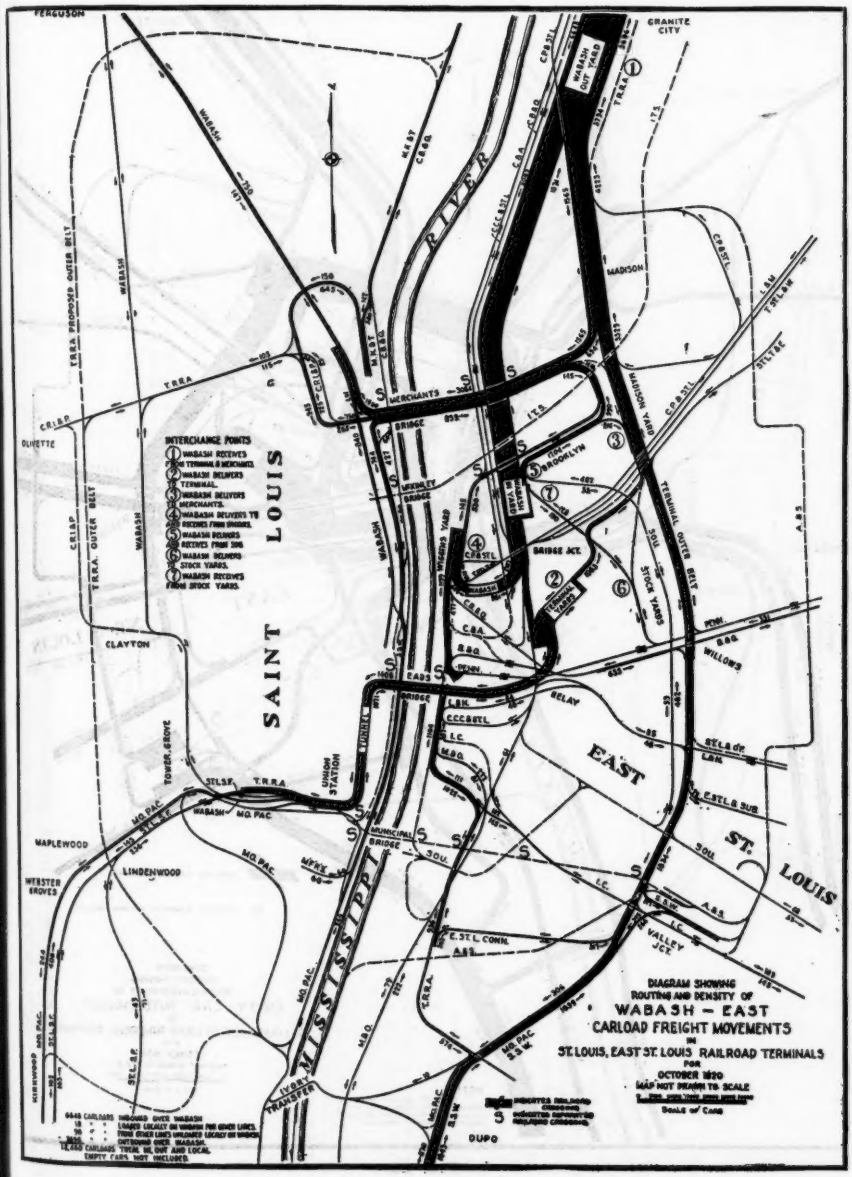

FERGUSON
GRANITE CITY
WABASH OUT YARD
RIVER
MISSISSIPPI
SAINT LOUIS
EAST ST. LOUIS
MADISON
MADISON YARD
MERCHANTS BRIDGE
MCKINLEY BRIDGE
EADS BRIDGE
MUNICIPAL BRIDGE
TERMINAL RAILROAD ASS'N
UNION STATION
BRIDGE ACT.
STOCK YARDS
TERMINAL OUTER BELT
T.R.R.A. PROPOSED OUTER BELT
CLAYTON
MAPLEWOOD
WEBSTER GROVES
LINDENWOOD
VALLEY JCT.
DUPO
INTERCHANGE POINTS
1 WABASH RECEIVES FROM TERMINAL & MERCHANTS
2 WABASH DELIVERS TO TERMINAL.
3 WABASH DELIVERS TO MERCHANTS.
4 WABASH DELIVERS TO & RECEIVES FROM SHORES.
5 WABASH DELIVERS TO & RECEIVES FROM 3RD.
6 WABASH DELIVERS TO STOCK YARDS.
7 WABASH RECEIVES FROM STOCK YARDS.
DIAGRAM SHOWING ROUTING AND DENSITY OF WABASH – EAST CARLOAD FREIGHT MOVEMENTS IN ST. LOUIS, EAST ST. LOUIS RAILROAD TERMINALS FOR OCTOBER 1920
MAP NOT DRAWN TO SCALE
Scale of Cars

FIG. 27.

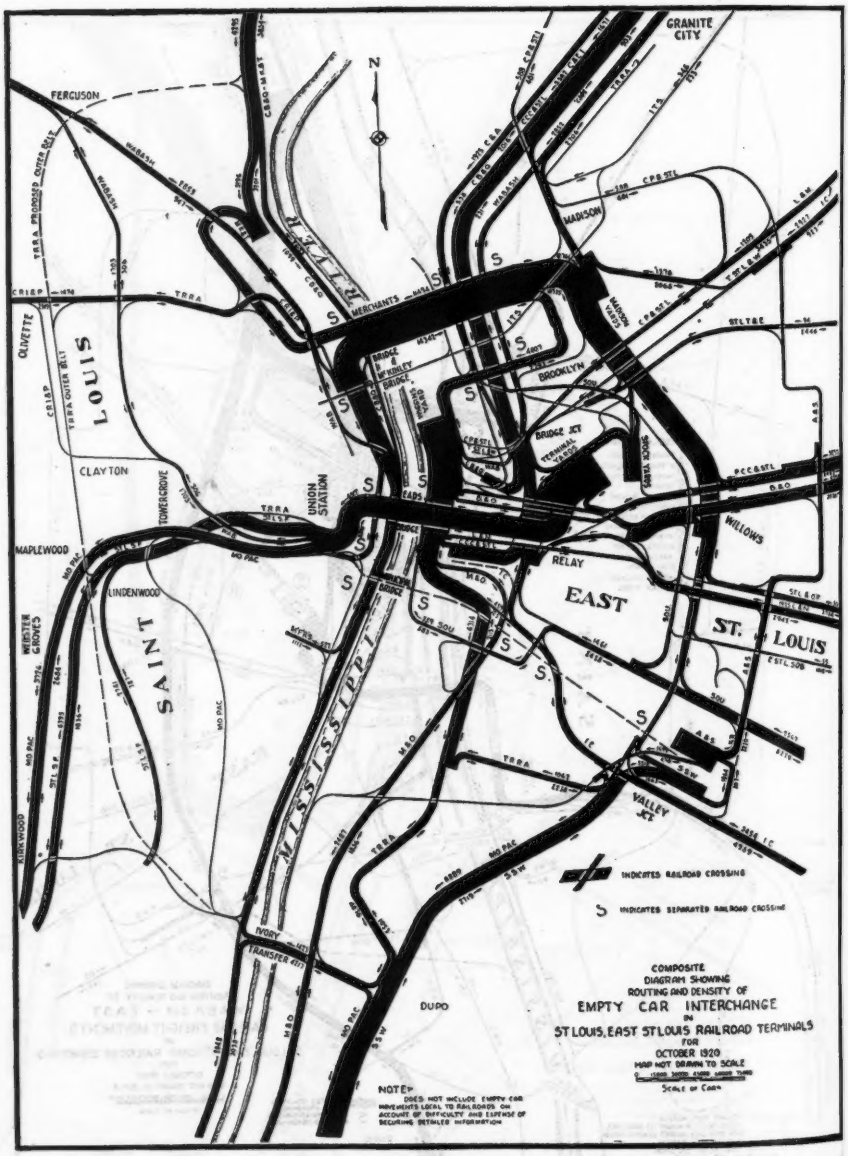


FIG. 28.

TABLE 8.—STATEMENT SHOWING NUMBER OF CARLOADS HANDLED BY EACH RAILROAD LOCAL TO ITS OWN TERMINALS AND IN CONNECTION WITH OTHER RAILROADS, MONTH OF OCTOBER, 1920.

TABLE 8.—STATEMENT SHOWING NUMBER OF CARLOADS HANDLED BY EACH RAILROAD LOCAL TO ITS OWN TERMINALS AND IN CONNECTION WITH OTHER RAILROADS, MONTH OF OCTOBER, 1920.

Railroads.	Inbound.				Outbound.				From Other Lines for Local Delivery.	Loaded Locally for Other Lines.	Total.	Per-centage.
	For Unloading on own Lines.		For Delivery to Other Roads.		Loaded on Own Lines.		Received from Other Roads.					
	Number.	Per Cent.	Number.	Per Cent.	Number.	Per Cent.	Number.	Per Cent.				
Baltimore and Ohio	549	11.4	4 292	88.6	449	9.9	4 079	90.1	264	546	10 179	3.7
Chicago and Alton	460	8.6	4 905	91.4	433	7.4	5 447	92.6	82	81	11 408	4.1
Chicago, Burlington and Quincy	1 708	14.6	10 067	85.4	2 342	23.2	7 747	76.8	1 127	318	23 309	8.4
Cleveland, Cincinnati, Chicago and St. Louis	2 034	35.3	3 739	64.7	560	11.2	4 349	88.8	104	111	10 897	3.9
Chicago and Eastern Illinois	470	17.6	2 197	82.4	215	6.9	2 880	93.1	.....	.....	5 762	2.1
Chicago, Peoria and St. Louis	128	8.1	1 453	91.9	278	12.8	1 898	87.2	58	.....	3 815	1.4
Chicago, Rock Island and Pacific	154	5.9	2 473	94.1	536	21.4	1 976	78.6	169	92	5 400	2.0
East St. Louis and Suburban	.....	....	2 824	100.0	.....	....	.....	....	.....	.....	2 824	1.1
Illinois Central	1 236	11.2	9 523	88.8	2 159	16.9	10 607	83.1	95	19	23 639	8.6
Illinois Traction System	172	36.0	307	64.0	438	51.8	406	48.2	126	7	1 456	0.5
Litchfield and Madison	.....	....	2 334	100.0	.....	....	.....	....	.....	.....	2 334	0.8
Louisville and Nashville	454	9.9	4 144	90.1	783	23.8	2 501	76.2	377	58	8 317	3.0
Missouri, Kansas and Texas	243	7.0	3 222	93.0	1 073	24.3	3 366	75.7	578	62	8 544	3.1
Missouri Pacific	3 397	14.5	19 960	85.5	3 458	18.6	15 140	81.4	8 560	3 002	53 517	19.6
Mobile and Ohio	388	8.2	4 320	91.8	788	18.5	3 239	81.5	84	9	8 778	3.2
Pennsylvania	1 609	27.0	4 375	73.0	700	11.4	5 428	88.6	772	869	13 753	5.0
St. Louis and O'Fallon	.....	....	1 946	100.0	.....	....	.....	....	.....	.	1 946	0.7
St. Louis—San Francisco	539	6.1	8 302	93.9	1 478	23.2	4 636	76.8	2 124	295	17 374	6.3
St. Louis South Western	120	2.7	4 418	97.3	818	23.3	2 682	76.7	126	.....	8 164	3.0
St. Louis, Troy and Eastern	.....	....	3 201	100.3	.....	....	.....	....	.....	.....	3 201	1.2
Southern	932	13.8	5 834	86.2	895	25.0	2 674	75.0	1 208	973	12 516	4.5
Toledo, St. Louis and Western	400	13.8	2 494	86.2	144	3.1	4 479	96.9	48	9	7 574	2.8
Wabash	2 625	19.3	10 948	80.7	2 153	20.1	8 551	79.9	5 373	570	30 220	11.0
Total	17 618	13.1	117 278	86.9	19 650	17.6	92 085	82.4	21 275	7 011	274 927	100.0

	Number of carloads for own lines.	Per cent.	Number of carloads in interchange.	Per cent.
Inbound	17 618	13.1	117 278	86.9
Outbound	19 650	17.6	92 085	82.4
	37 268	15.1	209 363	84.9

Fig. 29 shows the proposed location of the group yards, the grouping of the railroads, and the transfer routes. This arrangement would practically eliminate the multiplicity of interchange points now used, as shown in Fig. 15.

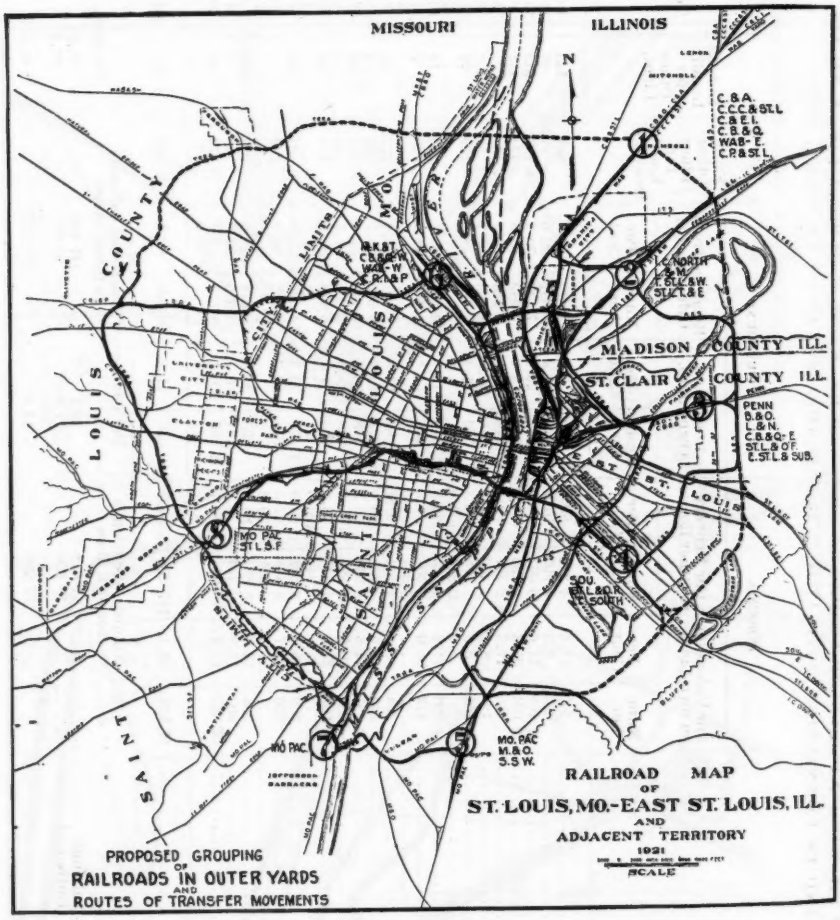


FIG. 29.

Table 9 shows the list of railroads convenient to each group yard and the number of carloads that would have passed through them in October, 1920.

The improvement that is expected to follow the proposed plan is graphically presented in Figs. 30 and 31. Fig. 30 is a composite diagram of the carload movements on all railroads, showing present conditions; Fig. 31 is a composite diagram for the same volume and character of business handled in the proposed manner.

The Committee considered and discarded the idea of a central clearing yard similar to the Chicago yard, for the reason that its use would involve a large amount of unnecessary additional mileage and delay through a congested

territory, and that better results could be obtained by having this work done in group yards located conveniently to the routes of the railroads. It has been recommended that the work which is now performed in more than forty individual freight yards be consolidated into eight group yards—five on the east side of the river and three on the west side. The locations chosen for these yards are points where railroad companies already own nearly or quite sufficient property and already have the nucleus of freight yards, thus requiring only modifications and extensions of present facilities in order to make the scheme effective.

TABLE 9.—NUMBER OF CARLOADS PASSING THROUGH LOCATIONS OF PROPOSED GROUP YARDS AND RAILROADS CONVENIENT TO EACH GROUP YARD.

Yard No. 1, North of Granite City: 26 500 carloads in. 25 551 carloads out. Chicago and Alton. Cleveland Cincinnati Chicago and St. Louis. Chicago and Eastern Illinois. Chicago Burlington and Quincy. Wabash (East). Chicago Peoria and St. Louis.	Yard No. 5 at Dupo: 22 200 carloads in. 16 195 carloads out. Missouri Pacific. Mobile and Ohio. St. Louis South Western.
Yard No. 2, Near Madison: 10 800 carloads in. 11 286 carloads out. Illinois Central (North). Litchfield and Madison. Toledo St. Louis and Western. St. Louis Troy and Eastern.	Yard No. 6, North St. Louis: 18 500 carloads in. 15 193 carloads out. Missouri Kansas and Texas. Chicago Burlington and Quincy (West). Wabash (West). Chicago Rock Island and Pacific.
Yard No. 3, East of Willows: 24 300 carloads in. 15 254 carloads out. Pennsylvania. Baltimore and Ohio. Louisville and Nashville. Chicago Burlington and Quincy (East). St. Louis and O'Fallon. East St. Louis and Suburban.	Yard No. 7, West Ivory: 4 800 carloads in. 2 277 carloads out. Missouri Pacific.
Yard No. 4, East of Valley Junction: 16 000 carloads in. 9 727 carloads out. Southern. St. Louis and Ohio River. Illinois Central (South).	Yard No. 8, Near West City Limits: 15 500 carloads in. 15 128 carloads out. Missouri Pacific. St. Louis-San Francisco.

Comparison of the car mileage by present routes through individual yards, and by proposed routes through outer group yards, indicated that there would be saved the yard switching of 1 800 000 cars and the movement of 10 000 000 car-miles per year, in addition to the elimination of an indeterminate amount of idle locomotive mileage. Unfortunately, the terminal records of the railroads were not kept so as to enable the Committee to determine the amount of money that would be saved, but it has been estimated by many railroad men that the saving would be in excess of $10 000 000 per year. Table 10 shows the relation between the car movements by the present and proposed methods.

The necessity was recognized of preserving to each railroad company its rights and privileges in the Industrial District. Some companies have very extensive terminal and track connections with shippers, whereas others depend entirely on the joint facilities of the Terminal Railroad Association. The plan

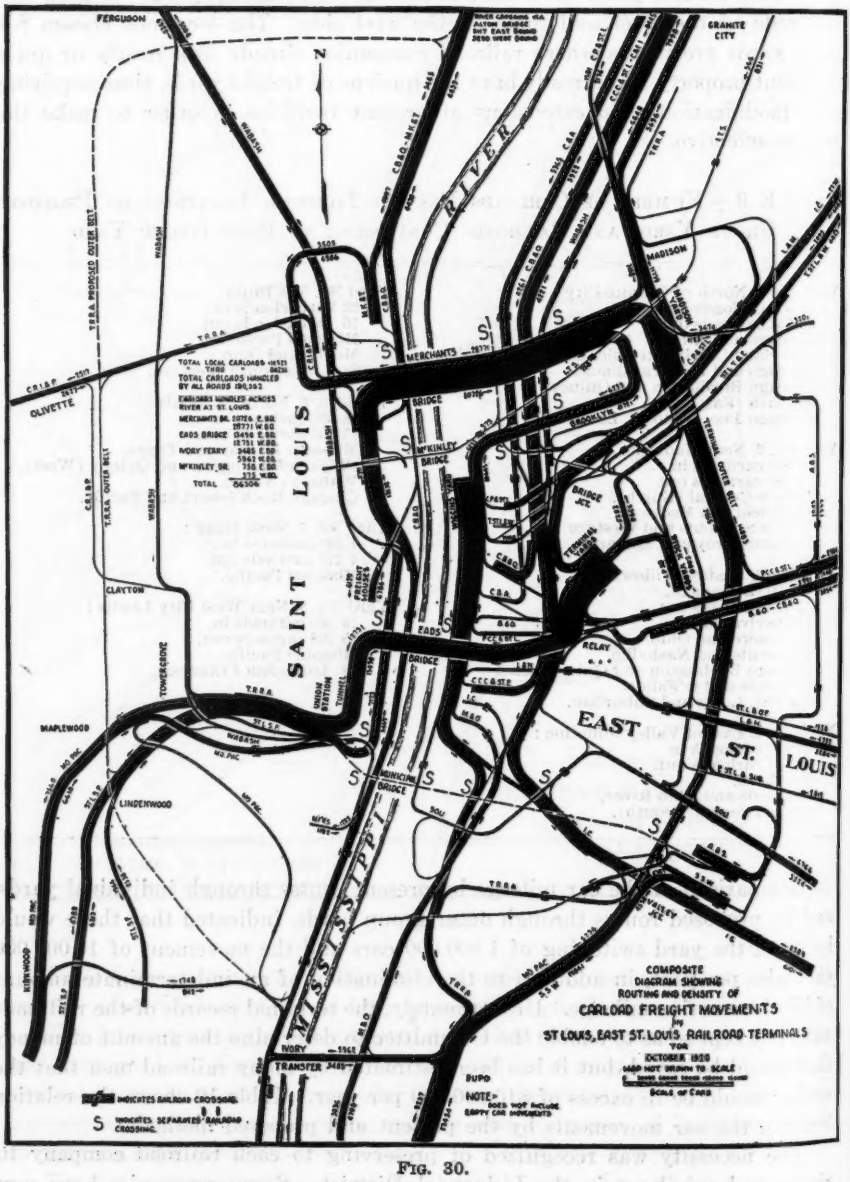

FERGUSON
GRANITE CITY
RIVER
MADISON
MERCHANTS
BRIDGE
McKINLEY
BRIDGE
EADS
BRIDGE
ST. LOUIS
SAINT LOUIS
EAST
ST. LOUIS
CLAYTON
MAPLEWOOD
LINDENWOOD
MISSISSIPPI
IVORY
TRANSFER
TERMINAL OUTER BELT
TERRA PROPOSED OUTER BELT
TOWER GROVE
TOTAL LOCAL CARLOADS 187121
TRIBS " 68134
TOTAL CARLOADS HANDLED BY ALL ROADS 190,382
TARLOADS HANDLED ACROSS RIVER AT ST. LOUIS
MERCHANTS BR. 107126 E.BD. 78771 W.BD.
EADS BRIDGE 63416 E.BD. 61751 W.BD.
IVORY FERRY 3485 E.BD. 5967 W.BD.
McKINLEY BR. 755 E.BD. 755 W.BD.
TOTAL 86306
COMPOSITE DIAGRAM SHOWING ROUTING AND DENSITY OF CARLOAD FREIGHT MOVEMENTS by ST. LOUIS, EAST ST. LOUIS RAILROAD TERMINALS FOR OCTOBER 1920
MAP NOT DRAWN TO SCALE
SCALE OF CARS
INDICATES RAILROAD CROSSING.
INDICATES SEPARATED RAILROAD CROSSING.
NOTE:- DOES NOT INCLUDE EMPTY CAR MOVEMENTS

FIG. 30.

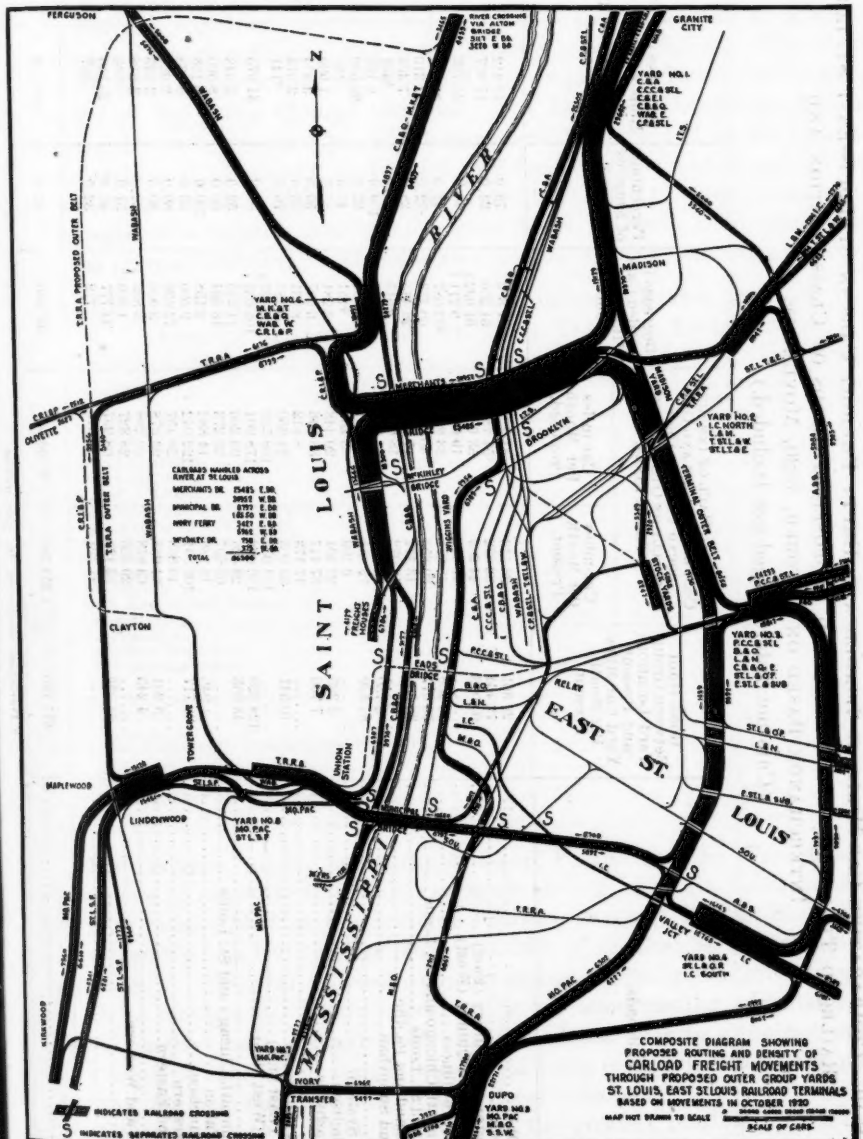

FERGUSON
GRANITE CITY
RIVER
SAINT LOUIS
MADISON
CLAYTON
MAPLEWOOD
LINDENWOOD
EAST ST. LOUIS
MISSISSIPPI
TERMINAL OUTER BELT
TRRA PROPOSED OUTER BELT
MERCHANTS BR.
MCKINLEY BRIDGE
EADS BRIDGE
TOWER GROVE
UNION STATION
VALLEY JCT
IVORY TRANSFER
DUPO
INDICATES RAILROAD CROSSING
INDICATES SEPARATED RAILROAD CROSSING
COMPOSITE DIAGRAM SHOWING PROPOSED ROUTING AND DENSITY OF CARLOAD FREIGHT MOVEMENTS THROUGH PROPOSED OUTER GROUP YARDS ST. LOUIS, EAST ST. LOUIS RAILROAD TERMINALS BASED ON MOVEMENTS IN OCTOBER 1920
MAP NOT DRAWN TO SCALE
SCALE OF CARS

FIG. 31.

TABLE 10.—COMPARATIVE CAR-MILES OF LOADED AND EMPTY FREIGHT CARS IN ST. LOUIS-EAST ST. LOUIS RAILROAD TERMINALS BY PRESENT AND PROPOSED METHODS OF CLASSIFICATION AND INTERCHANGE BASED ON OCTOBER, 1920, MOVEMENT.

(Cars not Interchanged not Included.)

Railroads.	Road Haul Between Group Yard Locations and Present Yard Car-Miles Per Month Present.	Terminal Haul of Inbound Connecting Line and Outbound Cars Loaded Locally on Other Than Trunk Lines.		Decrease in Loaded Car-Miles Per Month.	Percentage of Empties to Load.	Decrease in Empty Car-Miles Per Month.	Total Decrease in Car-Miles Per Month.
		Car-miles Per Month Present.	Car-miles Per Month Proposed.				
Baltimore and Ohio	22 601	36 510	41 229	17 882	75.0	13 412	31 294
Chicago and Alton	72 464	33 072	54 280	51 256	34.0	17 427	68 683
Chicago, Burlington and Quincy (East)	90 073	44 983	53 964	81 092	45.0	41 769	132 572
Chicago, Burlington and Quincy (West)	.....	29 371	19 660	9 711			
Chicago and Eastern Illinois	20 308	39 071	33 860	*15 087	47.0	*7 091	*22 178
Cleveland, Cincinnati, Chicago and St. Louis	70 077	30 853	40 277	60 153	72.0	43 310	103 463
Chicago, Peoria and St. Louis	30 830	13 172	17 559	26 443	28.0	7 404	33 847
Chicago, Rock Island and Pacific	.....	18 072	18 687	*615	70.0	*431	*1 046
East St. Louis and Suburban	2 750	28 884	23 968	2 166	100.0	2 166	4 332
Illinois Central	80 520	75 952	54 621	101 851	32.0	32 592	134 443
Illinois Traction System	.....	3 109	3 260	*151	40.0	*60	*211
Litchfield and Madison	2 325	20 404	20 448	2 281	85.0	1 939	4 220
Louisville and Nashville	7 736	37 417	38 246	6 907	50.0	3 454	10 361
Manufacturers	.....	17 173	8 412	8 761	23.0	2 015	10 776
Missouri, Kansas and Texas	10 541	34 005	23 650	*186	76.0	*141	*327
Missouri Pacific (East Side)	.....	164 053	159 526	4 527	38.0	41 975	152 435
Missouri Pacific (West Side)	128 229	156 608	178 904	105 933			
Mobile and Ohio	48 053	26 426	63 266	11 213	53.0	5 943	17 156
Pittsburgh, Cincinnati, Chicago and St. Louis	.....	68 607	55 273	13 334	60.0	8 000	21 334
St. Louis and O'Fallon	1 946	18 986	14 882	2 158	100.0	2 158	4 316
St. Louis-San Francisco	80 717	100 831	122 042	9 506	53.0	5 038	14 544
St. Louis Southwestern	.....	40 863	28 457	12 406	80.0	9 925	22 331
St. Louis, Troy and Eastern	3 201	24 083	23 378	3 906	80.0	3 125	7 031
Southern	4 245	63 878	62 288	5 835	62.0	3 618	9 453
Toledo, St. Louis and Western	.....	29 436	28 327	1 109	51.0	566	1 675
Wabash (East)	61 599	52 175	68 997	44 777	45.0	20 150	64 927
Wabash (West)	.....	47 291	46 519	772	32.0	247	1 019
Total	617 135	1 254 785	1 303 980	567 940	45.6	258 510	896 450

* Denotes increase in car-miles.

recommended by the Committee will preserve the balance between railroads by not taking away from any railroad any of its connections with shippers.

It is interesting to note that the Board of Economics and Engineering, appointed by the National Association of Security Owners, after a study of the Chicago situation, recommended practically the same kind of a group-yard plan for classification and interchange of carload freight. The Board went further, however, and recommended the complete unification under single control of the entire Chicago terminal. The St. Louis Committee does not believe this to be practicable. The latter might be unified if all the railroads possessed equal advantages in location and facilities, but, unfortunately, that is far from the case. This is well illustrated by Table 11, which indicates the relatively advantageous locations of some roads in comparison with others by the unequal distribution of industries that have track connections.

TABLE 11.—NUMBER AND PERCENTAGE OF INDUSTRIES SERVED BY EACH RAILROAD IN ST. LOUIS-EAST ST. LOUIS TERMINAL DISTRICT.

Railroads.	Number of industries.	Per cent.
Alton and Southern	21	1.4
Baltimore and Ohio	7	.5
Chicago and Alton	2	.1
Chicago, Burlington and Quincy	32	2.2
Chicago, Peoria and St. Louis	10	.7
Terminal Railroad Association	435	29.3
Illinois Traction System	18	1.2
Louisville and Nashville	24	1.6
Manufacturers	99	6.7
Missouri, Kansas and Texas	5	.3
Mobile and Ohio	3	.2
Missouri Pacific	370	25.0
St. Louis-San Francisco	57	3.8
St. Louis Southwestern	1	.1
Southern	74	4.9
Chicago, Rock Island and Pacific	13	.9
Pennsylvania	7	.5
Wabash	300	20.2
Cleveland, Cincinnati, Chicago and St. Louis	6	.4
Total number of industries	1 484	100.0

For instance, in St. Louis, the Missouri Pacific and the Wabash are in possession of extensive terminals having about 55% of all St. Louis industries on their rails. Likewise, the Southern Railway Company, in East St. Louis, by its ownership of a belt line has more than 25% of all East St. Louis industries on its rails. No other railroad company enjoys anything like the advantages of those mentioned. There appear to be no compensating advantages that would justify those roads turning their facilities over to a unified agency as a result of which their competitors would enjoy equal advantages and opportunities for road-haul business in their local terminals.

Although the Committee believes that the greatest possible unification of railroad terminals is desirable, it finds that such facilities in the St. Louis-East St. Louis District cannot be unified completely without unduly benefiting some and injuring other railroad companies, but that the interchange facilities and service should be unified to the extent indicated.

L. C. L. Freight

Table 12 and Fig. 32 show the location of the railroad freight-houses and how they are divided on the two sides of the river.

TABLE 12.—Showing Railroad Freight-Houses in St. Louis and East St. Louis.

West Side Railroads Having Houses Only in St. Louis: Chicago, Rock Island and Pacific, Missouri, Kansas and Texas, St. Louis-San Francisco.	**East Side Railroads Having Houses Only in East St. Louis:** Baltimore and Ohio, Chicago and Alton, Chicago, Peoria and St. Louis, Cleveland, Cincinnati, Chicago and St. Louis, East St. Louis and Suburban, Illinois Central, Mobile and Ohio, Southern, Toledo, St. Louis and Western.
West Side Railroads Having Houses Only in East St. Louis: None.	**East Side Railroads Having Houses Only in St. Louis:** Chicago and Eastern Illinois, St. Louis-Southwestern, Illinois Traction System.
Railroads Having Lines on Both Sides of River and Freight-Houses Only in St. Louis: Missouri Pacific.	**East Side Railroads Having Houses on Both Sides of River:** Pennsylvania, Louisville and Nashville.
Railroads With Lines and Freight-Houses on Both Sides of River: Chicago, Burlington and Quincy, Wabash.	
Terminal Companies Having Freight-Houses in St. Louis: Cupples Company, Terminal Railroad Association of St. Louis.	

Dating back to the time when there were no bridges across the Mississippi River, the east side lines terminated at the east bank of the river and located freight-houses and team tracks at that point. St. Louis freight handled by those lines was unloaded there and trucked across the river on ferries. After the ferries had been superseded by bridges, a few of the east side lines established freight-houses on the west side of the river. All the east side lines combined also in extending their service to a joint union freight-house provided by the Terminal Railroad Association. The delay in getting cars switched across the river was so great, however, and the shippers clamored so loudly for more direct service, that arrangements were made with transfer companies by which freight has been handled in trucks between St. Louis shippers and East St. Louis freight-houses. Some of this freight passes direct between shipper and railroad; some of it passes through intermediate transfer warehouses which are not located on railroad tracks, but are convenient to the St. Louis business district.

The east side lines pay the cost of trucking the freight across the river, not, however, to and from the shipper's door, but to the west bank of the river if it does not go through the warehouse and to the warehouse if handled in that way. In order to learn the flow of L. C. L. freight, 200 000 shipments were analyzed. The location of the shipper or consignee, the means of handling, the freight-house through which the freight passed, and other pertinent details were studied, recorded, and analyzed. Table 13 shows the number of tons of local and through connecting line freight handled by each road during the week of October 18 to 23, 1920. Table 14 shows the number of tons of freight handled across the Mississippi River by drays and by trap-cars during

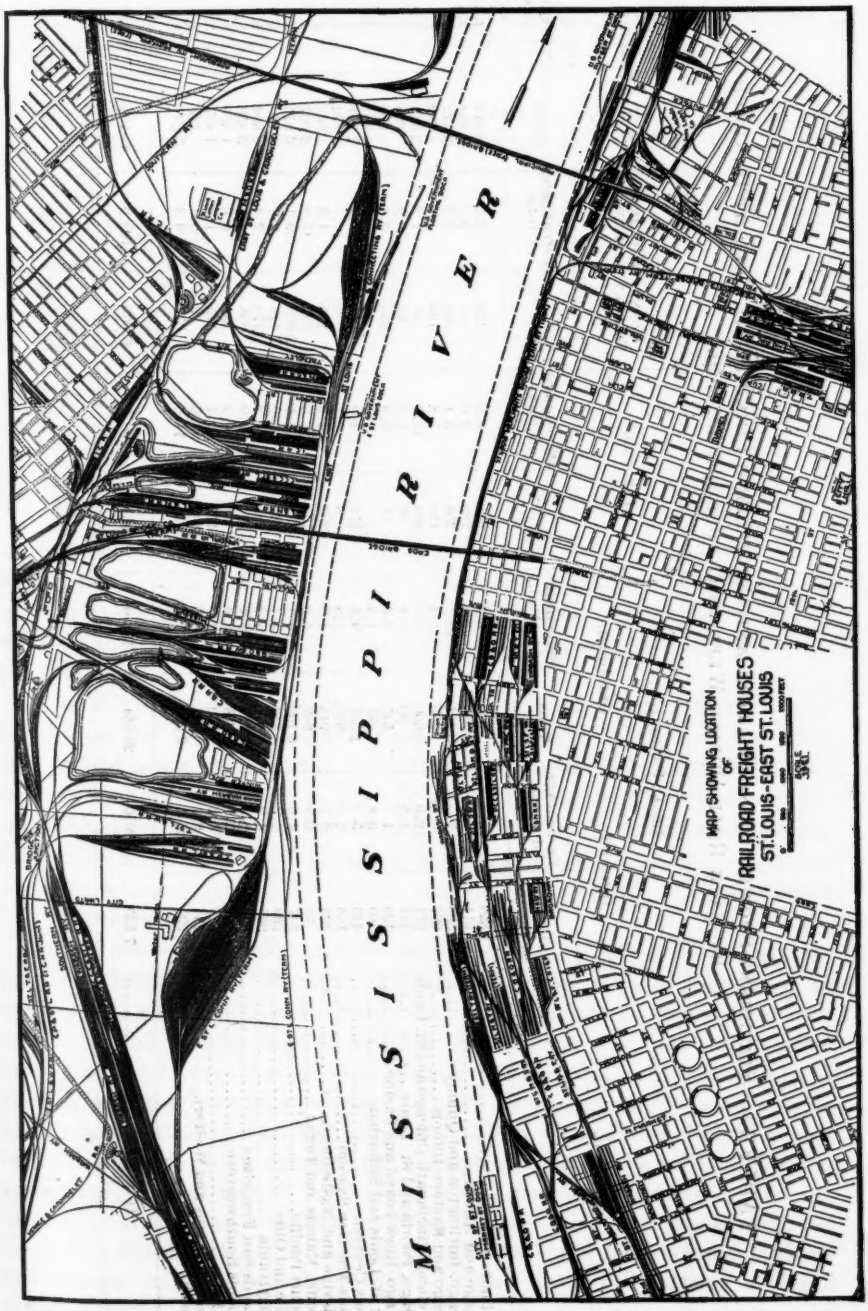

MISSISSIPPI RIVER
MAP SHOWING LOCATION OF
RAILROAD FREIGHT HOUSES
ST. LOUIS-EAST ST. LOUIS

FIG. 32.

TABLE 13.—STATEMENT SHOWING TONS OF LOCAL AND CONNECTING LINE L. C. L. FREIGHT HANDLED BY EACH ROAD DURING WEEK OF OCTOBER 18–23, 1920.

Roads.	Local Freight.				Inbound.		Connecting Line Freight Outbound.		Total Freight.	
	Inbound.		Outbound.							
	Tons.	Percentage of total.	Tons.	Percentage of total.	Tons.	Percentage of total.	Tons.	Percentage of total.	Tons.	Percentage of total.
Baltimore and Ohio	326	4.3	670	3.2	661	9.5	153	2.2	1 810	4.3
Chicago and Alton	511	6.8	520	2.5	293	4.0	141	2.0	1 454	3.5
Chicago, Burlington and Quincy	566	7.5	2 084	10.1	356	5.1	468	6.7	3 475	8.2
Chicago and Eastern Illinois	267	3.5	295	1.4	124	1.8	103	1.5	789	1.9
Cleveland, Cincinnati, Chicago and St. Louis	971	12.9	800	3.9	944	13.6	130	1.9	2 845	6.8
Chicago, Peoria and St. Louis	113	1.5	80	0.4	69	1.0	63	0.9	326	0.8
Chicago, Rock Island and Pacific	126	1.7	545	2.6	61	0.9	266	3.8	998	2.4
East St. Louis and Suburban	60	0.8	281	1.4	....	....	....	....	341	0.8
Illinois Central	443	5.9	1 957	9.5	277	4.0	224	3.2	2 901	6.9
Illinois Traction System	148	2.0	675	3.3	8	0.1	1	....	832	2.0
Louisville and Nashville	202	2.7	946	4.6	293	4.2	125	1.8	1 566	3.7
Missouri, Kansas and Texas	70	0.9	869	4.2	161	2.3	927	13.3	2 027	4.8
Missouri Pacific	347	4.6	3 108	15.1	592	8.5	2 028	29.1	6 075	14.4
Mobile and Ohio	169	2.2	842	4.1	131	1.9	118	1.7	1 260	2.9
Pennsylvania	366	4.9	877	4.3	981	14.2	170	2.4	2 394	5.8
St. Louis-San Francisco	226	3.0	2 220	10.7	204	2.9	806	11.5	3 456	8.2
St. Louis Southwestern	60	0.8	795	3.9	58	0.8	456	6.6	1 369	3.2
Southern	315	4.2	560	2.7	447	6.4	115	1.7	1 437	3.4
Toledo, St. Louis and Western	254	3.4	171	0.8	302	4.3	26	0.4	753	1.8
Wabash	1 965	26.4	2 339	11.3	1 016	14.5	647	9.3	5 997	14.2
Total	7 585	100.0	20 634	100.0	6 967	100.0	6 967	100.0	42 103	100.0

the same week. Table 15 shows the number of tons of freight handled at St. Louis and East St. Louis freight-houses that week and the means or agency through which they moved between railroad and shipper.

TABLE 14.—SHOWING TONS OF L. C. L. FREIGHT HANDLED ACROSS MISSISSIPPI RIVER, WEEK OF OCTOBER 18–23, 1920.

	By dray.	By car.	Total.
Between Freight Houses:			
West Side to East Side	761	271	1 032
East Side to West Side	3 518	1 090	4 608
Between Shipper and Freight Houses:			
West Side to East Side	8 225	1 662	9 887
East Side to West Side	433	.....	433
Total	12 937	3 023	15 960
Average tons per day	2 156	504	2 660
	81.1%	18.9%	100%

The study indicated that of all L. C. L. freight received in and shipped from St. Louis, 65% is handled direct by shippers to and from freight-houses located in St. Louis, and 35% is handled between shippers and east side freight-houses, crossing the river partly by trap-car, but to a much greater extent by motor truck.

Where shippers have the choice at the same railroad rate of either hauling to and from the east side freight-houses, or hauling to and from the joint union freight-house in St. Louis (involving a trap-car movement across the river), or hauling to and from the offtrack warehouse of the transfer companies, the great majority use the offtrack warehouse of the transfer companies, because they know that there is only a few hours' delay through the transfer warehouse, whereas there is a certainty of a delay of one day and a likelihood of more through the railroad union freight-house.

The Committee concluded and recommended that, by reason of the development and popularity of the offtrack transfer freight station, there was no reason for the east side lines to provide individual freight houses of their own in St. Louis and that the shipper would be much better served by a systematic development and extension of the offtrack station idea. The principle is adaptable to other busy communities. Freight-houses may be located outside the congested districts and operated in conjunction with offtrack freight-houses located at strategic points through the shipping district. The railroad freight-houses would be relieved of the burden of innumerable trucks each bearing small shipments, which would be replaced by full truck loads consolidated at the offtrack freight stations. In fact, connections could be developed between such offtrack stations and the railroad freight stations by means of rapid transit, elevated, and subway lines, as well as by motor trucks in the city streets.

TABLE 15.—SHOWING AMOUNT AND PERCENTAGE OF L. C. L. FREIGHT HANDLED BY DRAYS AND TRAP CARS, WEEK OF OCTOBER 18–23, 1920.

	At St. Louis Freight-Houses.				At East St. Louis Freight-Houses.			
	Inbound.		Outbound.		Inbound.		Outbound.	
	Tons.	Percentage.	Tons.	Percentage.	Tons.	Percentage.	Tons.	Percentage.
Columbia Transfer	242	5.9	1 809	13.9	1 419	41.2	3 850	50.0
Other Trucks and Drays	3 583	87.6	9 670	74.3	1 272	36.9	2 945	38.3
Terminal Railroad Association, Tenth Street	56	1.4	.....	.....	554	16.1	278	3.5
Cupples Station Drays	37	0.9	.....	.....	.....	.....	...	.....
Cupples Station Cars	67	1.7	1 045	8.0	146	4.3	495	6.4
Other Trap Cars	104	2.5	494	3.8	53	1.5	139	1.8
Total	4 089	100.0	13 018	100.0	3 446	100.0	7 702	100.0

St. Louis freight handled in St. Louis Freight-Houses	16 674 tons—65% of St. Louis freight.
St. Louis freight handled in East St. Louis Freight-Houses	9 887 tons—35% of St. Louis freight.
East St. Louis freight handled in St. Louis Freight-Houses	483 tons—25% of East St. Louis freight.
East St. Louis freight handled in East St. Louis Freight-Houses	1 261 tons—75% of East St. Louis freight.
Total	28 255 tons

The shipper has the great advantage of being able to take all his shipments, even though consigned over several railroads, to a single freight-house closer to his place of business than the railroad freight-houses, of making one stop and on unloading of all the packages. At the offtrack station, all small shipments would be separated and consolidated into vehicles for direct movement to and from railroad freight-houses. In connection with such offtrack stations, store door delivery can be developed.

The distribution of the L. C. L. freight throughout the District was first determined by localizing it in more than 100 zones, then into 35 larger zones, and then into 8 zones for St. Louis and 6 for the entire District as shown in Fig. 33. This study showed that 80% of the freight is attributable to 20% of the District.

Figs. 34 and 35 show graphically the intensity of use of the freight-houses and the cost of handling the freight in them. Fig. 36 shows graphically the movement of L. C. L. connecting line freight that moves through St. Louis from one railroad to another. About 75% moves by dray through the city streets and 25% moves by railroad cars.

The Committee recommended that attention be given to the development of multiple-story buildings in connection with railroad freight-houses, as has been done and considered elsewhere as illustrated in Figs. 37 and 38.

Grade Crossings

Within 1½ mile of the East St. Louis river-front, near the east end of the Eads Bridge, in a distance of 1 mile, there are twenty-five points where railroads cross other railroads at grade as shown in Fig. 39. The confusion which results from it is indescribable. If three of the railroad companies involved in that disorder will consent to exchange their freight-houses on an equitable basis, each to use one of the others, six of those grade crossings will be eliminated, as shown in Fig. 40. By a further re-arrangement, a total of sixteen of the grade crossings may be eliminated. Nine appear to be necessary for proper internal circulation.

In approaching East St. Louis, the Baltimore and Ohio Railroad comes in south of the Pennsylvania Railroad and runs alongside, until they reach the east end of Eads Bridge. There they cross at grade putting the Baltimore and Ohio north and the Pennsylvania south, at the throat of the freight-house layouts of the two roads.

No general study of the grade crossing problem was attempted. St. Louis has not a serious grade-crossing situation, but one that can be handled piecemeal. East St. Louis, however, by reason of the fact that 20 railroads scattered broadcast over the ground before the city became of importance, is now hemmed in at every point by more than 200 grade crossings. Recognizing the need of attention to this subject, however, the Committee formulated the following recommendation:

"Each railroad should study its highway grade crossing problems in the St. Louis-East St. Louis terminals with representatives of the various communities; general plans should be agreed to for the future elimination of such crossings as it seems desirable to eliminate at some future time, and there-

MAP AND STATEMENT SHOWING DISTRIBUTION OF L.C.L. FREIGHT HANDLED IN AND OUT OF THE ST. LOUIS-EAST ST. LOUIS DISTRICT WEEK OF OCT. 18-23, 1920
NOTE— FIGURES SHOWN IN HATCHED AREAS ARE ZONE NUMBERS AND PERCENTAGES OF ST. LOUIS FREIGHT IN THOSE ZONES
SCALE
EAST SIDE 6.7%
4-3.4%
6-1.8%
5-8.0%
3-10.4%
2-18.1%
1-56.1%
7-2.2%
CITY LIMITS
ZONE No.

FIG. 33.

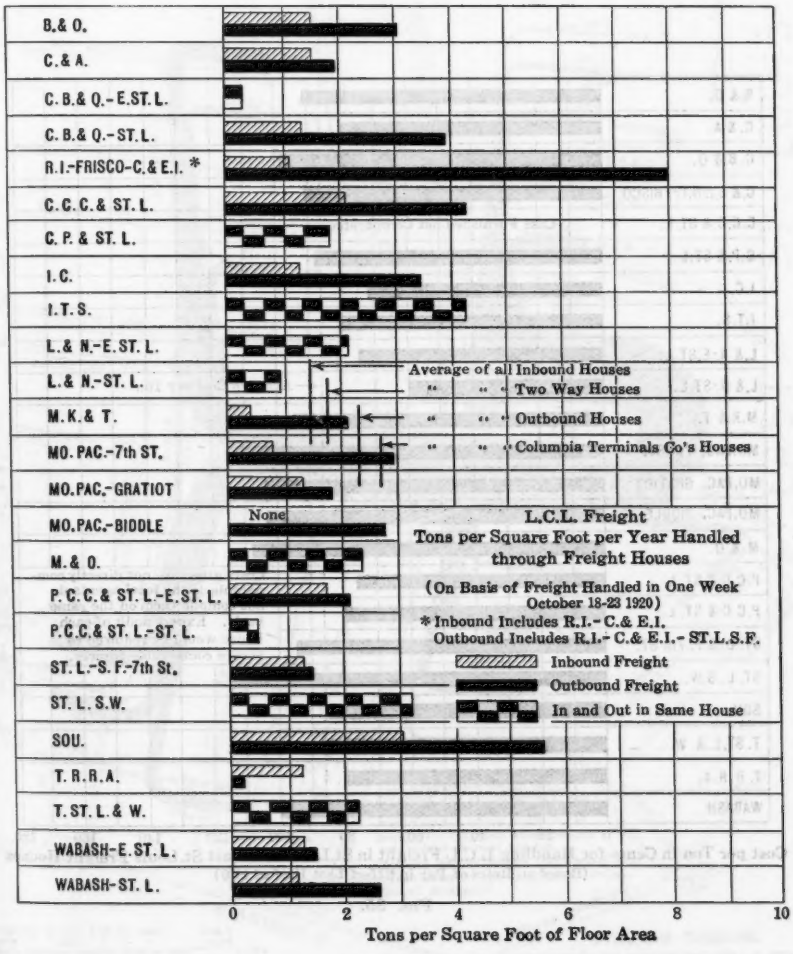
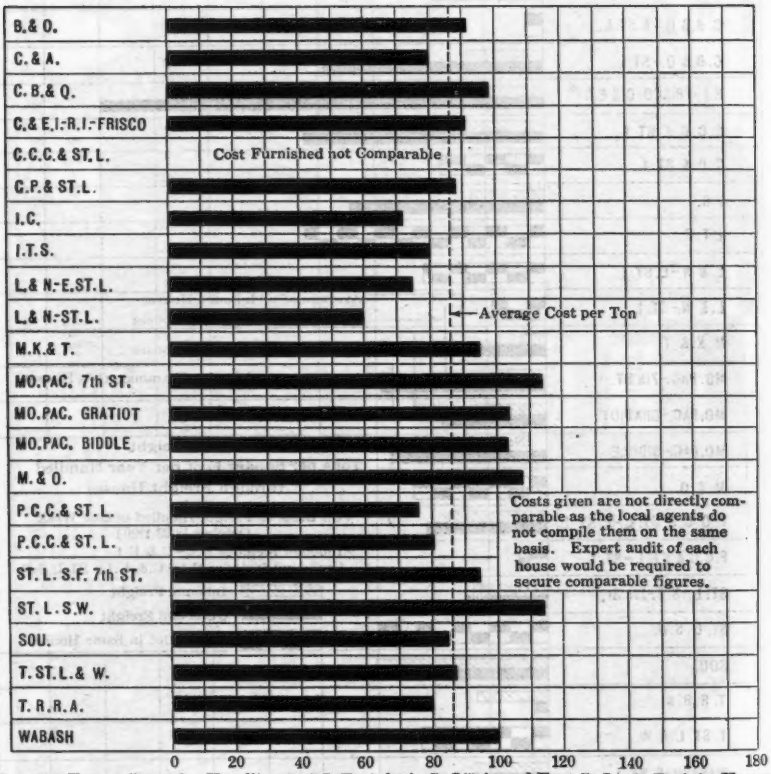

B.& O.
C.& A.
C. B.& Q.-E.ST.L.
C. B.& Q.-ST.L.
R.I.-FRISCO-C.& E.I. *
C.C.C.& ST. L.
C. P. & ST. L.
I.C.
I.T.S.
L.& N.-E.ST.L.
L.& N.-ST.L.
M.K.& T.
MO. PAC.-7th ST.
MO.PAC.-GRATIOT
MO.PAC.-BIDDLE
M.& O.
P.C.C.& ST.L.-E.ST.L.
P.C.C.& ST.L.-ST.L.
ST.L.-S.F.-7th St.
ST.L.S.W.
SOU.
T.R.R.A.
T.ST.L.& W.
WABASH-E.ST.L.
WABASH-ST.L.
None
Average of all Inbound Houses
" " " Two Way Houses
" " " Outbound Houses
" " " Columbia Terminals Co's Houses
L.C.L. Freight
Tons per Square Foot per Year Handled through Freight Houses
(On Basis of Freight Handled in One Week October 18-23 1920)
* Inbound Includes R.I.- C.& E.I.
Outbound Includes R.I.- C.& E.I.- ST.L.S.F.
Inbound Freight
Outbound Freight
In and Out in Same House
0
2
4
6
8
10
Tons per Square Foot of Floor Area

FIG. 34.



Cost per Ton in Cents for Handling L.C.L Freight in St.Louis and East St.Louis Freight Houses
(Based on Rates of Pay in Effect Last Half of 1920)

FIG. 35.

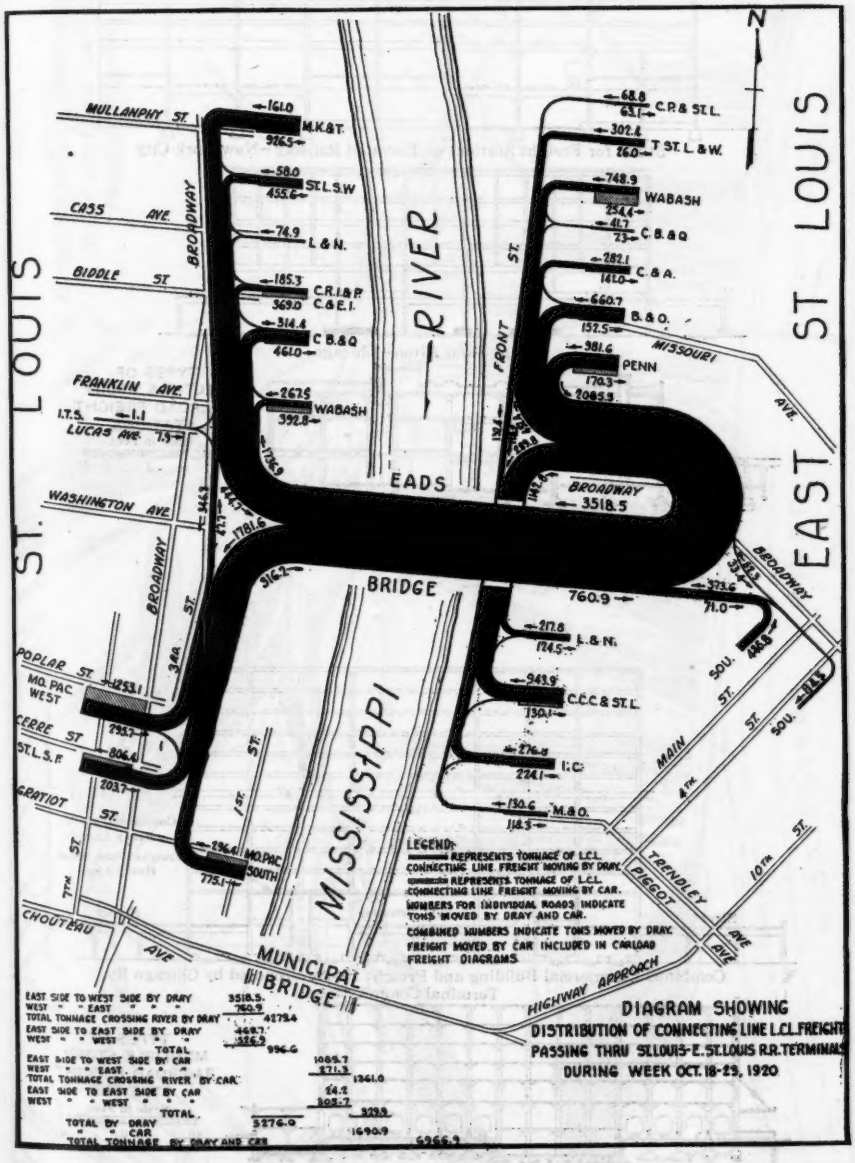
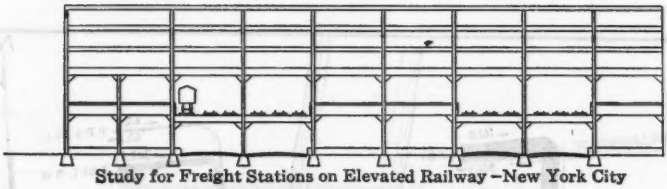
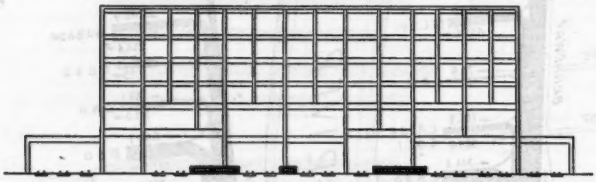

N
MULLANPHY ST.
M.K.&T.
CASS AVE.
ST.L.S.W.
BROADWAY
BIDDLE ST.
L & N.
C.R.I.&P.
C.&E.I.
C.B.&Q.
FRANKLIN AVE.
WABASH
I.T.S.
LUCAS AVE.
WASHINGTON AVE.
ST. LOUIS
RIVER
EADS
BRIDGE
MISSISSIPPI
FRONT ST.
C.R.& ST.L.
T.ST.L.&W.
WABASH
C.B.&Q.
C.&A.
B.&O.
MISSOURI AVE.
PENN
BROADWAY
3518.5
EAST ST LOUIS
POPLAR ST.
MO. PAC. WEST
CERRE ST.
ST.L.S.F.
GRATIOT ST.
MO.PAC. SOUTH
CHOUTEAU AVE.
MUNICIPAL BRIDGE
HIGHWAY APPROACH
L & N.
C.C.C.& ST.L.
I.C.
M.&O.
MAIN ST.
TRENDLEY AVE.
PIGGOT AVE.
SOU. ST.
10TH ST.
4TH
7TH
1ST
5TH
LEGEND:
REPRESENTS TONNAGE OF L.C.L. CONNECTING LINE FREIGHT MOVING BY DRAY.
REPRESENTS TONNAGE OF L.C.L. CONNECTING LINE FREIGHT MOVING BY CAR.
NUMBERS FOR INDIVIDUAL ROADS INDICATE TONS MOVED BY DRAY AND CAR.
COMBINED NUMBERS INDICATE TONS MOVED BY DRAY.
FREIGHT MOVED BY CAR INCLUDED IN CARLOAD FREIGHT DIAGRAMS.
EAST SIDE TO WEST SIDE BY DRAY 3518.5
WEST " " EAST " " " 760.9
TOTAL TONNAGE CROSSING RIVER BY DRAY 4279.4
EAST SIDE TO EAST SIDE BY DRAY 468.7
WEST " " WEST " " " 328.9
TOTAL 996.6
EAST SIDE TO WEST SIDE BY CAR 1065.7
WEST " " EAST " " " 271.3
TOTAL TONNAGE CROSSING RIVER BY CAR 1361.0
EAST SIDE TO EAST SIDE BY CAR 14.1
WEST " " WEST " " " 303.7
TOTAL 329.9
TOTAL BY DRAY " " CAR 3276.0 1690.9
TOTAL TONNAGE BY DRAY AND CAR 5266.9
DIAGRAM SHOWING
DISTRIBUTION OF CONNECTING LINE L.C.L. FREIGHT
PASSING THRU ST.LOUIS-E.ST.LOUIS R.R. TERMINALS
DURING WEEK OCT. 18-23, 1920

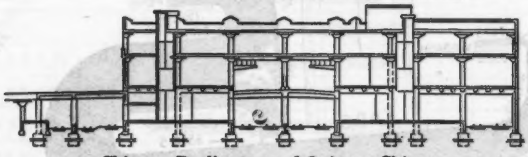
FIG. 86.



Study for Freight Stations on Elevated Railway—New York City

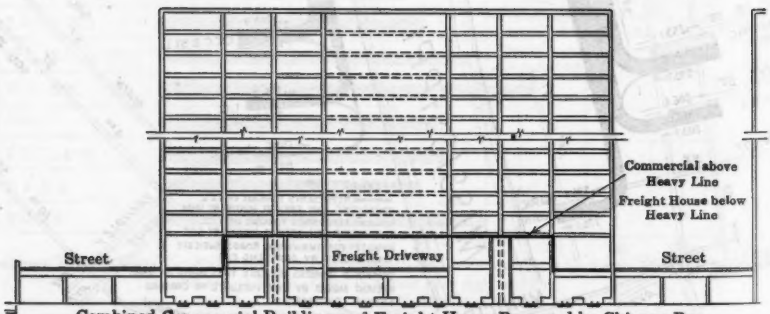


Chicago and Alton—Chicago

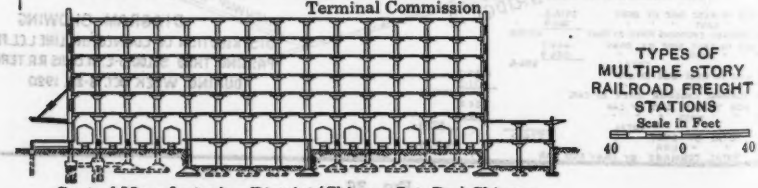


Chicago, Burlington and Quincy—Chicago

FIG. 37.



Combined Commercial Building and Freight House Proposed by Chicago Ry. Terminal Commission



Central Manufacturing District (Chicago Jct. Ry.) Chicago

FIG. 38.

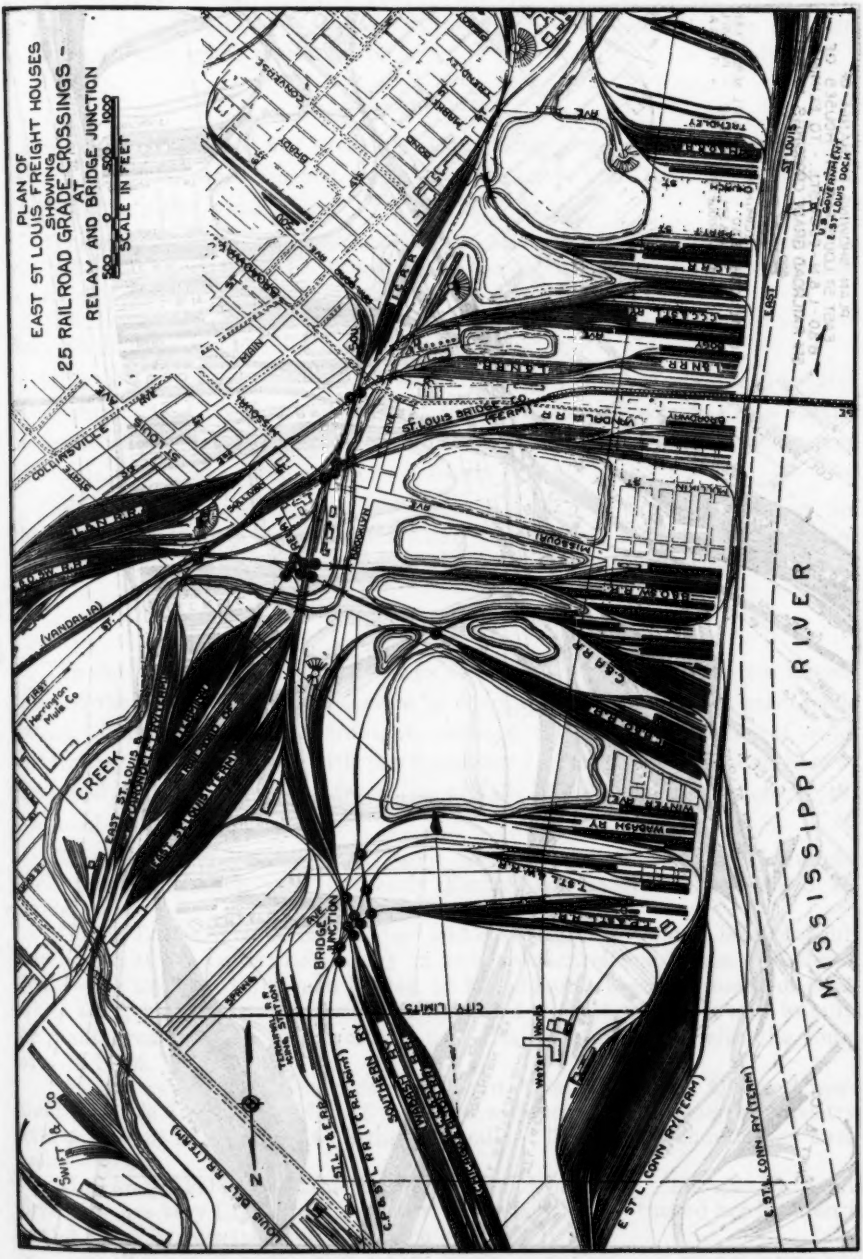

PLAN OF
EAST ST LOUIS FREIGHT HOUSES
SHOWING
25 RAILROAD GRADE CROSSINGS -
AT
RELAY AND BRIDGE JUNCTION
SCALE IN FEET
MISSISSIPPI RIVER
CREEK
CITY LIMITS
N

FIG. 39.

PLAN SHOWING EXCHANGE OF
EAST ST LOUIS FREIGHT HOUSES OF
B&O - L&N - CCC&STL - TO ELIMINATE
SIX RAILROAD GRADE CROSSINGS AT RELAY
SCALE IN FEET
0 500 1000
ELIMINATES
CCC&STL ACROSS B&O
PCC&STL
EADS BRIDGE APP
CCC&STL ACROSS L&N
RCC&STL
TRRA
B&O
L&N
CCC&STL
CB&Q R.R.
MISSOURI PACIFIC R.R.
ST LOUIS BRIDGE CO
TERMINAL R.R.
CREEK
EAST ST LOUIS JUNCTION
CITY LIMITS
EAST
ST LOUIS
U.S. GOVT. FOUR MILE
E. ST. LOUIS DOCK
SOUTHERN RY
CHESTNUT ST. (ILL. 157)
E. ST. L. CONN RY (TERM.)
SWIFT & CO.
COLLINSVILLE

FIG. 40.

after in locating industries and making improvements, nothing should be done by either the railroads or the communities that would make it more difficult to eliminate any grade crossings."

Electrification

Some consideration was given to electrification, with the result that the same conclusions were reached as in Chicago a few years ago, which may be expressed in a few words thus:

"The complete elimination of steam locomotives from the railroad terminals of St. Louis and East St. Louis for smoke abatement is not under present-day conditions necessary.

"The complete electrification of the railroad terminals of St. Louis and East St. Louis is financially impracticable."

It is interesting to note that a recent suggestion of a prominent official of the St. Louis City Government that the railroads be electrified as a means of smoke abatement was met with unanimous adverse comment in newspaper editorials, which was summarized by one editor as follows:

"Whenever St. Louis can say—'We have freed our city of smoke, except for the railroads and we demand electrification' there will be a good chance of completing the job. Until such a showing can be made, the railroad project is folly."

River-Front

The development of river traffic was recognized and the Committee recommended that the river and rail service be co-ordinated to the fullest practicable extent. The St. Louis river-front, in common with the river-fronts of other river cities, has gone down with the decadence of river traffic and can best be described by quoting again from the article of Frederich Simpich in the *National Geographic Magazine:*

"When the pioneer Americans went west, floating down the Mississippi, their first destination was that early French fur-traders' colony called St. Louis.

"But if La Salle came back today, and came again by water, he'd probably never land at St. Louis; he'd hurry on to a prettier, cleaner place. Maybe in 1682, when this first white man landed, he found here a beautiful beach of clean white sand, leading back to grassy slopes lined with stately elms and walnuts or giant sycamores—a lush, verdant land, its pure air filled with the songs of wild birds.

"As late as Dickens' time this river front, this old 'French Quarter' mentioned in his 'American Notes,' was not without color, music, and poetry. It was vibrant and restless with the gay, gallant life of that tumultuous antebellum epoch.

"But unspeakably desolate it is now, and depressing. Though St. Louis first drew her very life from the great river, today she has turned her back on it—and a shabby, weatherbeaten, forlorn old back it is.

"The 19 miles of waterfront, which might be parked—all grassy lawns and flower beds, with groves of shrubs and shade trees, as charming as New York's famous Riverside Drive or the restful roads that Washington has thrown along the Potomac—form the sad truth probably the ugliest river front in all America.

"The majestic river, the greatest on our continent, is actually shut off from view, invisible to the real St. Louis, by the old, dilapitated buildings that fringe it."

The difference between the old St. Louis river-front and the new river terminals that are being provided, is well illustrated by Figs. 41 and 42.

Conclusion

No estimate was made of the cost of the improvements and changes that would be required, as it was recognized that the Committee was preparing a railroad plan for the community similar to a city plan for a city. On this feature, the Committee had the following to say:

"In arriving at the conclusions and recommendations enumerated below and discussed more in detail in this report, the Committee has endeavored to foresee and provide for the transportation needs of the St. Louis-East St. Louis Industrial District for a long period of time. Some of the improvements should be undertaken immediately, others may not be required for several years. The improvements are so extensive that they must necessarily be extended over a considerable period of years.

"It is most important, however, that the various affected interests agree upon definite plans and methods and that thereafter those plans and methods should be the goal toward which all improvements are directed. No step should be taken that would conflict with them.

"With that end in view a committee representative of the carriers and the public should be created to concern itself with the execution of these improvements in their logical order, and to study such further details as time and changing conditions may warrant, to the end that there may be established an ultimate plan and policy of gradual and economical improvement of this terminal in harmony with its needs, and in harmony with other related physical improvements."

After the Committee's report was rendered, a series of meetings were held by representatives of the public and the railroad companies, as a result of which the entire engineers' report was accepted in principle by the railroad companies and their willingness has been expressed to go ahead with the work. An ordinance granting the railroad companies the rights they must have from the public is now in preparation, and the partial, if not the complete, unification of freight-handling at St. Louis is in sight.

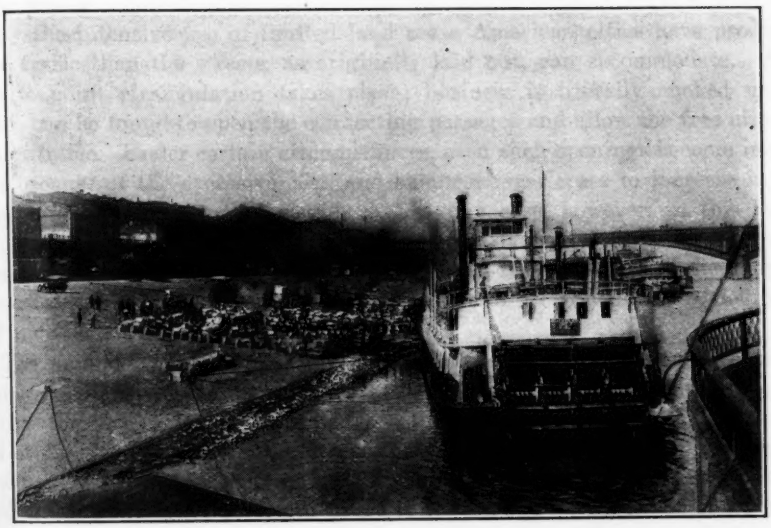


FIG. 41.—VIEW OF OLD RIVER FRONT AT ST. LOUIS, MO.

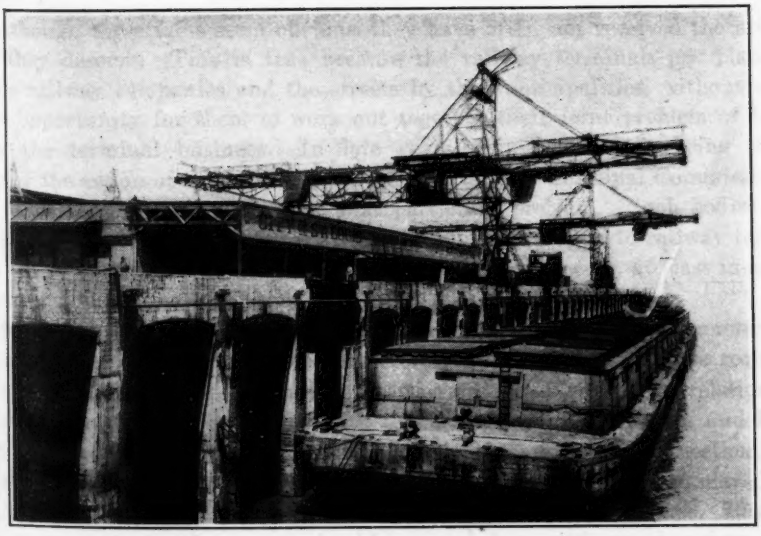
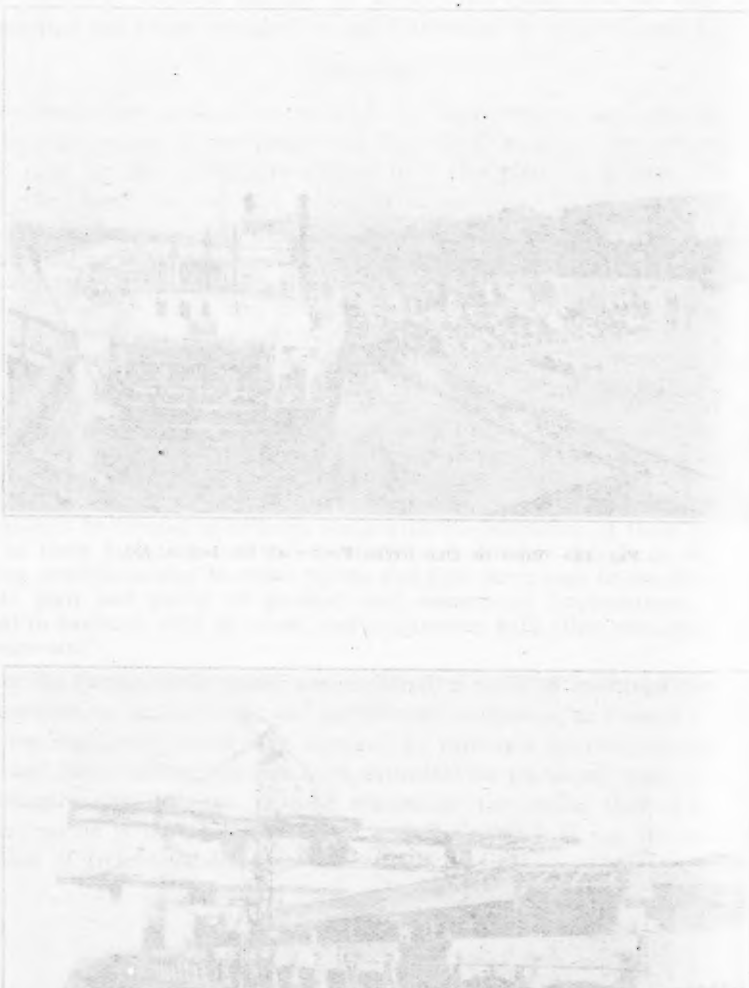


FIG. 42.—VIEW OF NEW RIVER TERMINALS AT ST. LOUIS, MO.



STREET DEVELOPMENT IN RELATION TO RAILROAD TERMINALS

By Jacob L. Crane, Jr.,* Assoc. M. Am. Soc. C. E.

By the intensive use of limited land areas American cities have produced more traffic than the streets, as originally laid out, can accommodate. At a definite point strangulation takes place; business is literally choked unless means can be found to open the connecting passages and allow the free circulation of traffic. Under certain circumstances, even such openings become impossible because of the excessive cost, and business must cease to increase in the areas concerned and spread elsewhere. In any case, however, in this battle for the use of land areas in crowded cities, the means of circulation to and between railroad terminals, both passenger and freight, must be kept open; otherwise, the entire economic fabric of the life of a city will suffer, definitely and inevitably.

The problem of economical and convenient handling of railroad terminal business is made up of two elements, the transfer before reaching or after leaving the terminal, and the transfer within the terminal itself. It does not end at the door of the passenger terminal, nor at the platform of the freight terminal. In fact, of the total cost, in time and money, to deliver people or goods from their point of origin to a railway car, say, at least one-half must usually be assigned to that part of the journey over public streets before the portal of the terminal is reached. Moreover, the field for effecting future economies in the transfer of passengers and goods is more promising in the consideration of better facilities over the city streets than within the terminals themselves.

Although these facts seem obvious, they have often not received the attention they deserve. This is true because the railway terminals are planned by the railway companies and the streets by the municipalities, without adequate opportunity for them to work out together their joint problem of handling the terminal business. In late years, this difficulty is being overcome by the action of City Plan Commissions, Railway Terminal Commissions, and Joint Committees assigned to that particular problem. Such bodies are developing a definite technique of street planning in relation to railway terminals. It is this technique which the speaker wishes to discuss, at least in some of its fundamental aspects.

In general, the requirements for streets intended to serve passenger terminals are somewhat different from those for freight terminals. These requirements, therefore, will be outlined separately. Street planning in relation to passenger terminals is concerned with the movement of passengers and baggage back and forth between a terminal and the business and hotel section, the transit lines, and other terminals. The passengers and baggage are moved on foot, in taxicabs, private cars, trucks, and busses, and by transit lines. Ideally, this movement over the streets should be carried on with speed, safety, and

* Municipal Development Engr., Chicago, Ill.

convenience, and at low cost; which means, first, direct routes; second, pavements adequately wide and properly graded and surfaced, and, finally, convenient access and parking space at the terminals.

Street planning in relation to freight terminals is concerned with the movement of freight by truck and team between the terminal in question and industrial districts, warehouse and commercial districts, and other terminals. Separate routes are desirable for this slower moving traffic which requires a different type of street for its greatest convenience: Heavier, rougher pavements, wider traffic lines, flatter grades, little or no provision for pedestrian movement, and specially designed loading and turning courts at the freight terminals.

Under each general heading there are special cases which involve special consideration, such as produce freight terminals and exclusively suburban passenger terminals.

These fundamental requirements for streets to serve passenger and freight terminals are simple enough in their mere statement, but they are more difficult to meet in actual practice. As has been suggested, the main point of the whole topic is that most city street systems have been developed without even an attempt to outline the simplest of these fundamental requirements. Let us see whether the volume of traffic created by the railroad terminals is sufficient to justify taking it into consideration as one of the main factors which must control the planning of city streets.

The total traffic load, on the busiest streets of Chicago, varies from 3 000 vehicles and 3 000 pedestrians to 30 000 vehicles and 30 000 pedestrians per day. These figures can be compared with the volume of traffic produced by typical terminals in the United States.

In Boston, the North Station* handles about 25 000 through passengers and 70 000 suburban passengers daily, a total of 95 000; the South Station handles a total of more than 125 000 persons daily. It is estimated that 1% of the suburban passengers and 10% of the through passengers leave the terminal in motor vehicles of one kind or another.† Allowing two people to a motor car, the Boston terminal passenger business develops upward of 4 000 motor vehicle trips and more than 240 000 pedestrian trips each day.

This volume of business is the source of half of all the passenger and pedestrian traffic at certain points in the most crowded streets of Boston, and is the cause of intolerable congestion outside the stations themselves. When it is considered that the peak of this traffic load coincides with the rush-hour load of other street business, between 5:00 and 6:00 P. M., the importance of the terminal traffic is even more striking.

Passenger, vehicle, and pedestrian traffic in volumes comparable to those estimated for Boston are produced in New York and Chicago, although the effect is less critical, because of the somewhat more convenient street systems,

* Figures from reports of Chicago Railway Terminal Commission.

† At the Chicago and Northwestern Passenger Terminal, in Chicago, 2% of the suburban and 15% of the through passengers use taxicabs.

and, in Chicago, because the passenger business is divided among six main stations instead of two.

Using the most recent available figures* on Chicago package freight, it is found that about 17 000 tons of freight per working day are handled over team-tracks, 7 000 tons are delivered by teams and trucks to outbound freight-houses, and 5 000 tons are taken by teams and trucks from inbound freight-houses, a total of 30 000 tons per day. This figure represents at least 25 000 truck movements per day over city streets.† Although there is no peak to this traffic load to coincide with the rush hours, it does continue through those hours, and a large part of it does necessarily move over streets already congested by other traffic, and on those streets, by its own bulk and slow speed, it offers the largest single obstruction to free traffic movement.

One-fourth of all the daily passenger vehicle traffic on the Washington Boulevard Bridge (the busiest east and west bridge in Chicago) is made up of taxicabs going to and from the Chicago and Northwestern Station. More teams and trucks pass over South Water Street in and out of the Illinois Central freight terminal in a day than along any other street in the City of Chicago. One-fourth of all the pedestrian traffic in down-town Chicago flows to and from the railroad terminals every day.

These figures give an idea of the importance of terminal traffic in any street-planning project. They also suggest the fundamentals of street planning and development, namely, that such planning should be done for a particular anticipated volume and character of traffic. Before actually planning streets, the designers should have data to indicate:

(*a*).—The character of the various quotas of traffic for which the street is to be planned, distinguishing them as pedestrian and vehicular, commercial and pleasure, trucks and light vehicles.

(*b*).—The volume of these quotas of traffic and the hourly and daily variation in the volume.

(*c*).—The speed of the typical vehicles, which will depend less on the potential speed of the vehicle itself than on the conditions of travel, such as crowding and character of pavement.

(*d*).—The width, length, and weight of the vehicles to be handled.

(*e*).—The origin and destination of the vehicles and pedestrians.

(*f*).—The nature of parking and loading space required, and the time for loading or waiting.

(*g*).—Special factors, such as traffic regulations, and of course, projected re-arrangements of streets.

In order to anticipate the volume and character of the traffic which a certain street or system of streets is to accommodate, a traffic census each year for a series of years will indicate the rate of increase in volume of traffic and also tendencies in its changing character—the kind, size, speed, and weight of vehicles. Automobile traffic has been increasing at a rapidly accelerating

* October, 1921, Chicago Railway Terminal Commission.

† At the Illinois Central and Michigan Central freight yards near the river, east of Michigan Avenue in Chicago, 4 400 tons of L. C. L. freight handled by teams and trucks create about 4 000 team and truck trips per day.

rate for the last ten years, and now it is possible to anticipate this increase up to the point of saturation for an existing density of business and population. After the point of saturation is reached, the problem becomes one of anticipating the rate of growth of business, industrial and residential sections, and particularly the tendencies toward large movements in the location of these districts. Zoning plans are of great assistance in these studies. They show the prospective character and density of development in all parts of a city for a period of 20 to 40 years ahead, and usually, in fact, for all time to come. If the same group that prepares the zoning plans also co-operates in working out the street plan, the most fundamental and authentic information will be available for anticipating the growth and tendencies in industrial and residential development. This information is also useful in planning the railroad terminals themselves as well as in planning the streets to serve the terminals.

Almost equally important to the anticipation of growth and development of the city are considerations of tendencies in terminal design. The projected intensive business development in buildings constructed over the electrified terminals in Chicago will produce an enormous volume of street traffic different in character and requirements from the terminal traffic proper. The tendency to consolidate terminals and to create general freight stations promises larger volumes of traffic from the sites of the enlarged plants, with a corresponding decrease from the abandoned sites, unless the latter is developed for other uses.

Branch terminals, through routing, extension of trap-car, tunnel, or water transfer, all tend to decrease the traffic load on crowded streets and sometimes to distribute it on less crowded thoroughfares. In fact, this is one good reason for adopting these expedients where the development of terminals has exceeded the capacity of the street system to handle the traffic produced, and the improvement of the street system is impracticable or less economical than the expedients named.

The dominant conclusion of all these considerations is that the street system and terminal system should be planned together. The common sense necessity of this plan of procedure is further reinforced when the topic of grade-crossing elimination is suggested. No program of making safer streets by eliminating grade crossings can be conceived without involving the whole question of terminal location.

There is also an important consideration from the architectural standpoint. The newer railway terminals of North America are by far the handsomest in the world. Their settings, however, are almost without exception so inadequate that the fine architecture is largely wasted, because it cannot be seen. The ideal situation for a fine terminal building would seem to be on a large plaza opening off special streets which, in turn, connect with main thoroughfares, and, in each case, the terminal should be located in full view on the axis of two or more streets converging on the plaza. Fig. 43 illustrates several examples.

Where the re-arrangement of streets is necessary in order to provide for terminal business, the cost has usually been borne by the municipalities, by

special assessment against abutting property, or by a combination of the two. In a few cases the terminal companies have borne part or all of the cost. It is understood that the cost of widening Canal Street in Chicago is borne by the Union Station Company, the property of which it serves.

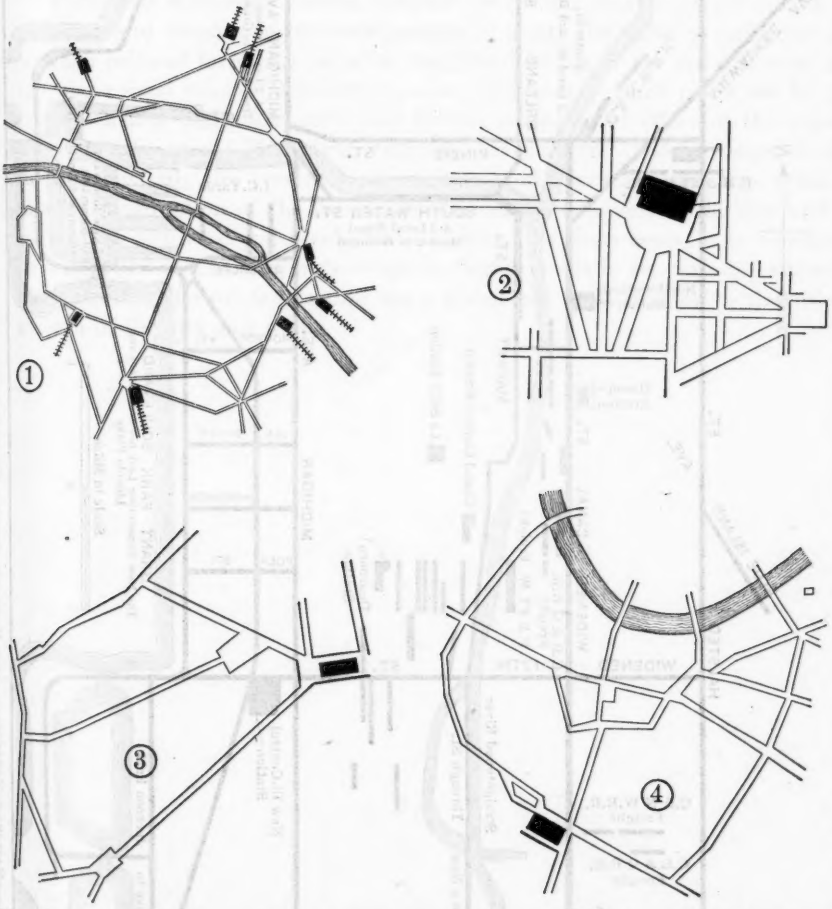


FIG. 43.—PASSENGER TERMINALS AND PRIMARY STREETS: (1) PARIS; (2) WASHINGTON; (3) FRANKFORT; and (4) DRESDEN.

Probably the most notable example in this country of street planning and development to serve adequately a huge and comprehensive terminal plan is that worked out by the Chicago Plan Commission and now being adapted by that Commission in conjunction with the railroads and other interests, and carried out in construction by the Board of Local Improvements of the City and, in the case of the lake front improvements, by the South Park Commission. The general plan is illustrated in Fig. 44.* At this time, the new Michigan Avenue Bridge and the lower level crossing from the Illinois Central yards under Michigan Avenue have been completed. The Roosevelt Road project is under

* Reproduced from the publications of the Chicago Plan Commission.

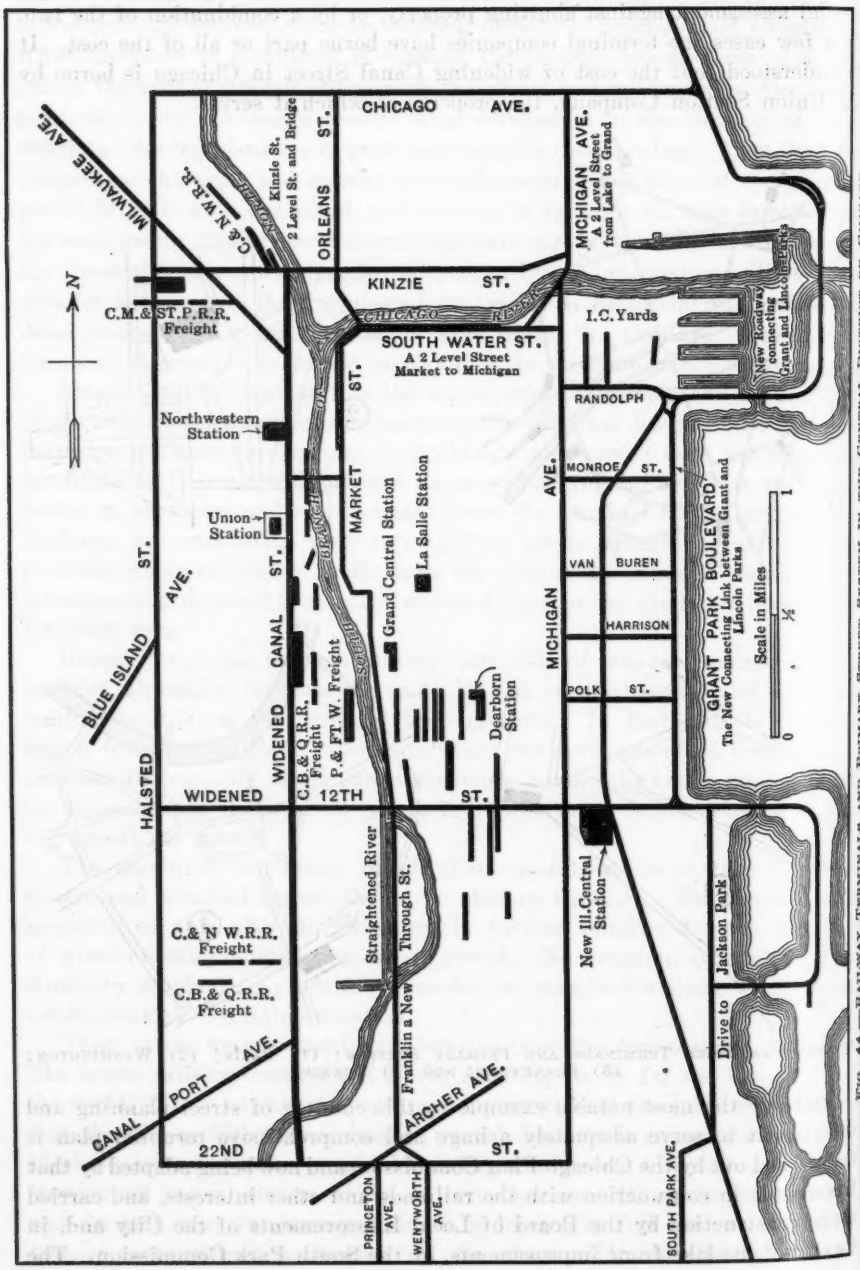


FIG. 44.—RAILWAY TERMINALS AND PRIMARY SCHOOL SYSTEM IN THE CENTRAL DISTRICT OF CHICAGO.

construction. The South Water Street project is under ordinance; the outer drives along the Lake are definitely projected; and the Market Street project only awaits a final settlement of the terminal plans to take concrete shape for actual construction.

From this discussion certain definite conclusions may be briefly stated: In planning and developing the street system of a city the traffic to and from and between railroad terminals must be considered as one of the main factors, and the plans must propose definitely to serve this traffic. Such plans can be prepared sensibly and adequately only by the co-ordinated effort of the various interests concerned: Municipal, railroad, and private. The necessary studies include not only the present tendencies in traffic increase, but also a fundamental examination of the future growth and development of the city and its industrial, business, and residential districts. In some cases, it is reasonable to charge the cost of necessary street re-arrangements to the terminal improvement itself. The whole question has a direct and vital relation to the orderly growth of the city as a whole.

CHICAGO TERMINAL IMPROVEMENTS, ILLINOIS CENTRAL RAILROAD

By D. J. Brumley,* M. Am. Soc. C. E.

The Illinois Central Railroad Company's lake-front problems in Chicago, Ill., including its terminal improvement, will be more easily understood if a brief statement is made of the facts controlling the location of the railroad along the shore of Lake Michigan and the early history of the Railroad Company's property in the city. The railroad was chartered in 1851. At that time, the Company was naturally desirous of securing a location in the city which would place the freight and passenger terminals convenient to the business district, and likewise in a position for easy and expeditious interchange with other railroads.

The occupation of the lake front would not meet these conditions. The Company surveyed a line and requested the City Council to permit the construction of the railroad along the south branch of the Chicago River from the southern limits to the central part of the city. The City Council declined to consider any location other than that the railroad should intersect the lake shore at the foot of present 51st Street and occupy the lake front north to the Chicago River.

At that time, the southerly city limits were at 22d Street. The city authorities had previously incurred very large expenditures in attempting to protect the shore line and the improvements contiguous thereto from destruction by storm and waves of the lake. Michigan Avenue was then a narrow street along the shore and its protection from the lake was a serious problem. About $12 000 had been raised by the authorities for a bulkhead protection, but, in 1851, a storm destroyed this protection and did so much damage at Madison and Monroe Streets that Mayor Gurney, who lived in that vicinity, had the fire-bells rung and called out the citizens in force to help protect the city.

By interposing a railroad between the city and the lake it was thought that the railroad would be obligated, for its own protection, to maintain breakwaters, dikes, and other protective devices, thereby relieving the city of very considerable expense. In an editorial of April 2, 1852, *The Daily Democrat* urged a franchise to the Railroad Company with a requirement contained therein that the Company should forever protect the city from the action of the lake, stating "our lake shore needs protection, and if we do not succeed in having the railroad do it, we do not know how it can be done."

The ordinance with this provision was reluctantly accepted by the Railroad Company and within a few years the breakwater was completed from the river to 22d Street, the then city limits, the Railroad Company having spent more than $500 000 in this shore protection. As the city grew, the limits were extended southwardly from time to time, and the obligation of the Railroad Company to maintain the lake-front protection was extended automatically.

* Chf. Engr., Chicago Terminal Improvements, Ill. Cent. R. R., Chicago, Ill.

Finally, the Company was required to assume the entire expense of lake-front protection the whole length of its route contiguous to the lake shore, nearly 6½ miles, and has spent millions of dollars in carrying out this part of the contract.

At the time of the construction of the railroad, Chicago had a population of 30 000, and it was then thought that the lake shore would be of little, if any, value to the city. However, the need of the city to make use of Lake Michigan for transportation, and the lake shore for recreational, purposes soon became apparent. Harbor District No. 1, including the Chicago River and the lake shore north thereof, was established on July 28, 1913. Harbor District No. 2, extending from the southerly limits of District No. 1 to 16th Street was established on April 2, 1916, and by the provisions of the Lake Front Ordinance, passed July 21, 1919, the harbor limits were extended from 16th Street to 31st Street, and this extension is Harbor District No. 3.

Between Randolph Street and East 11th Place the title to the right of way consisted of an easement granted by the City authorities, but from East 11th Place south, the Railroad Company had title in fee simple to the right of way and abutting riparian rights.

Prior to 1895, Grant Park, west of the railroad, between Randolph Street and East 11th Place, had been reclaimed as a park for the public and, in 1896, the Company lowered the plane of its tracks north of East Roosevelt Road. About this time, the South Park Commissioners began the reclamation of the lake front between Randolph Street and East 11th Place, east of the railroad, for an additional park area. Accesses to these park areas have been provided by constructing viaducts over the right of way and tracks at Randolph, Monroe, Van Buren, Harrison, and Eighth Streets. Prior to 1893, an extensive area, known as Jackson Park, the site of the World's Fair, had been developed by the South Park Commissioners between 56th and 67th Streets, lying between Stony Island Avenue and Lake Michigan.

Previous to, and in anticipation of, the boundary line agreement with the South Park Commissioners, the Railroad Company consented to the location of the Field Museum of Natural History on lands which it had reclaimed, and thereby made possible, within the time specified by the donor, the dedication of this magnificent gift to the City of Chicago.

The demand for a continuous city playground along the entire lake front became so urgent that negotiations were entered into by the South Park Commissioners and the Railroad Company to fix an easterly boundary line of the lands of the Railroad Company and thereby confirm in the Commissioners the right to reclaim park areas, establish bathing beaches, and construct lagoons connecting Grant Park, opposite the Loop District of the city, with Jackson Park on the South Side. In 1912, the boundary line was definitely fixed by an agreement between the Railroad Company and the Commissioners. The Railroad Company relinquished the remaining riparian rights, in favor of the South Park Commissioners, to the lake front, which had not theretofore been sacrificed by contract, ordinance, or otherwise. This agreement did not authorize either the Railroad Company or the Commissioners to fill in sub-

merged land until the approval and authority of the Secretary of War had been obtained. The Secretary of War refused the application made by the South Park Commissioners and the Railroad Company to fill in any of these submerged lands until the plans were approved by the City of Chicago and specific provision was made for a southerly extension of the Harbor District then ending at 16th Street.

The so-called Lake Front Ordinance, of July 21, 1919, is, in fact, a three-party contract entered into by the City of Chicago, the South Park Commissioners, and the Illinois Central Railroad Company. It confirms the provisions of the contract of 1912 between the Railroad Company and the South Park Commissioners, provides the Harbor District demanded by the United States Government, and grants to the South Park Commissioners the right to fill in certain submerged areas east of the lands of the Railroad Company, to establish driveways, lagoons, bathing beaches, and recreational centers, and to construct viaducts over the right of way and tracks of the Railroad Company at East Roosevelt Road, 23d, 31st, and 35th Streets, Oakwood Boulevard and 43d Street, and subways at 18th and 47th Streets, thereby giving convenient and adequate accesses to the park areas, the new Field Museum, the Stadium (now under construction), and to the newly created Harbor District.

The South Park Commissioners are working out a program to develop the park area between Grant and Jackson Parks by building breakwaters, filling in the submerged lands, constructing viaducts and subways between the city and the park area, constructing a stadium, establishing bathing beaches, playgrounds, etc.

The rights granted to the Railroad Company by the Lake Front Ordinance provide for:

1.—To fill in and reclaim five slips north of Randolph Street, and the submerged area between the shore and the agreed boundary line south of East Roosevelt Road, reclaiming 107 acres.

2.—The reconstruction and enlargement of the suburban terminal at Randolph Street, as well as the reconstruction of suburban stations throughout the terminal area between Randolph Street and Matteson, and the South Chicago and Blue Island Branches, all of which are affected by electrification.

3.—The reconstruction and enlargement of the local freight terminal at South Water Street, and the widening and reconstruction of the viaduct, 1 725 ft. long, over the tracks and right of way at Randolph Street.

4.—The construction of a new passenger terminal and office building, mail and express building, concourse, train-sheds and appurtenances, with the necessary railroad tracks south of and adjoining East Roosevelt Road. The location of the passenger station at this point necessitates the re-location and widening, by the Railroad Company, of Indiana Avenue from a width of 66 to 100 ft. from Roosevelt Road to 16th Street.

As the through passenger terminal is constructed, the street changes will be made and the subway, 680 ft. in length, will be constructed at 18th Street. The first section of the through passenger terminal will be completed and

that part of the terminal ready for service when the suburban electrical operation is begun.

5.—The construction of tracks, buildings, platforms, driveways, engine houses, machine shop, storehouses, fuel station, coach yards, power plants, substations, and overhead transmission and distribution systems, in preparation for electrical operation.

6.—The construction of additional tracks on the main line between the Chicago River and Matteson and also on the South Chicago, Blue Island, and Kensington and Eastern Railroads.

7.—The re-location of that part of the St. Charles Air Line, which interferes with the development of the through passenger terminal.

8.—The construction of an "18th Street Railroad Connection" with facilities not to exceed six tracks extending from the Railroad Company's westerly right-of-way line, in the vicinity of 18th Street, to a connection with the Illinois Central and with the Atchison, Topeka and Santa Fe Railroad tracks in the neighborhood of Archer Avenue, and to make connections with all railroads in that vicinity. This will be an elevated railroad, crossing over all intersecting railroads, streets, avenues, alleys, and public places.

9.—The Railroad Company is required to assume the cost of lowering the plane of its tracks between 29th and 44th Streets to a minimum elevation of +4 and to raise the plane of its tracks between 44th and 51st Streets to permit of the construction of viaducts and subways by the City authorities and the South Park Commissioners connecting the city streets with the park and harbor developments. The change in the elevation of tracks between 29th and 51st Streets necessitates the reconstruction of the retaining wall along the west right-of-way line between these limits. The work of changing the plane of the tracks and the reconstruction of the retaining walls was begun in the summer of 1922 and will be finished during the latter part of 1924, and involves the rebuilding of the breakwater for the greater part of the distance, filling in the submerged area, lowering or raising the eight main and other supplemental tracks under traffic, constructing additional tracks, reconstructing signal system, relocating, diverting, and lowering city sewers within the area, and protecting the 20-ft. discharge outlet sewer crossing under the railroad tracks from the 39th Street Pumping Station of the Sanitary District.

10.—In addition to making these physical changes in the major facilities, the Railroad Company has consented to change the method of propulsion from steam to electric within the stated times provided in the ordinance for the different classes of service.

11.—The Railroad Company will, when Harbor District No. 3 develops, provide three railroad accesses which may be used by any railroad entering Chicago; the term for joint use, if not mutually agreed to by the interested parties, may be settled by the Interstate Commerce Commission.

12.—Permission is given any railroad entering Chicago to make use of the lake-front passenger facilities, either on terms mutually agreed to or on terms fixed by the Interstate Commerce Commission.

13.—The provisions of the Lake Front Ordinance apply to the Michigan Central Railroad Company also, as to reconstruction of its terminals, and electrical operation within the city limits.

It is predicted that the Loop, or down-town business, district of the immediate future will extend from the Chicago River on the north, to East Roosevelt Road on the south, the east and west boundary lines being, respectively, Lake Michigan and the south branch of the Chicago River.

A railroad terminal to serve best the purposes of a transportation machine must lie within easy and convenient reach of this great business center and furnish adequate and uninterrupted means of transportation for suburban and through passenger service and local freight business. In order that these three classes of business may be served adequately and without interference, they should comprise separate and distinct units of the terminal development, have ample connections with other railroads for expeditious interchange, and proper provision for adequate vehicular traffic accesses and local transportation connections.

The suburban passenger terminal is located between Randolph Street and the Chicago River and practically alongside Michigan Avenue, with stations at Randolph Street, Van Buren Street, and East Roosevelt Road, along the eastern side of the business section.

The plans developed thus far provide for a stub-end terminal at Randolph Street with two track levels, each consisting of six tracks of sufficient length to accommodate not less than 12-car trains. The operation of suburban trains throughout the terminal will be on tracks used exclusively for this service and without interruption from the operation of through passenger, freight, or switching trains. From Randolph Street to East Roosevelt Road, the operation of the suburban trains will be confined to four main tracks; from East Roosevelt Road to 47th Street, to six main tracks; from 47th Street to 67th Street, to four main tracks; from 67th Street to 115th Street, to three tracks, and from 115th Street to the southerly suburban terminus at Matteson, to two main tracks. At the through passenger terminal at East Roosevelt Road, the suburban tracks will occupy a tunnel, with station facilities below the level of the through passenger facilities. On the main line south, the suburban main tracks will occupy the westerly side of the right of way, where for the greater part of the distance, they will be most convenient to the patrons of this service.

The suburban terminal at Randolph Street will be completely reconstructed and that at Van Buren Street will be greatly extended and enlarged, with suitable subway connections under Michigan Avenue to each.

The local freight terminal of the Railroad Company lies east of Michigan Avenue and occupies an area of approximately 80 acres between Monroe Street and the Chicago River. The new freight terminal will be constructed with depressed driveways and track levels and will occupy a space of 55 or 60 ft. vertically below the boulevard and viaduct levels on two sides of the property. The heavy vehicular traffic street accesses will be underneath the boulevard viaduct approaches.

The through passenger terminal will be located at the intersection of Michigan Avenue (the principal north and south boulevard thoroughfare east of the river) and East Roosevelt Road (the future principal east and west boulevard thoroughfare). The area for the through passenger terminal development, comprising 102 acres, extends from East Roosevelt Road to 31st Street, a distance of 2¼ miles, with an average width of 640 ft., and has a frontage of 693 ft. on East Roosevelt Road where the passenger terminal buildings will be located.

East Roosevelt Road Boulevard, 118 ft. wide, will front the station on the north and extend into Grant Park, east of the railroad, on the north side of the Field Museum. Provision is made in the ordinance for the construction of a street-car tunnel under the right of way and tracks of the Railroad Company immediately north of the new station, with a stairway connection from the street-car tunnel to the station building. An ample park boulevard will adjoin the station on the east, and for a distance of ½ mile, Indiana Avenue, with no sidewalk on the east side, will be a widened traffic street adjoining the terminal area on the west.

In addition to these accesses, the through passenger terminal will have immediate connections with the Railroad Company's suburban service, and will be alongside two surface lines and one elevated line serving the principal residence districts of the city and adjoining a rapid transit subway, when built, in accordance with the City's present plan.

The terminal station building will be opposite the southerly end of Grant Park and will serve as a fitting southerly finial for this section of the park area. Immediately east of the terminal station building is the Field Museum of Natural History with which the station building will harmonize in general architectural appearance and color.

The Lake Front Ordinance has fixed the elevation of viaducts and subways in the vicinity of the through passenger terminal area so as to permit of the greatest latitude in developing track, platform, baggage, and mail levels. When the growth of the lake-front passenger terminal should require, it is practicable to construct one through-track level and two stub-track levels and have easy and permissible gradients on the main-track approaches for each level. The subway at 18th Street is placed at such elevations as not to interfere with the track approaches to the lowest track level.

The East Roosevelt Road Viaduct is the northerly limitation as to viaduct construction, the 23d Street Viaduct being the southerly limit, within the passenger terminal area. Within this area, and with the elevation of viaducts and subways as they have been fixed by the Lake Front Ordinance, it is possible to develop a passenger terminal with a capacity of approximately eighty tracks, none of which will be less than 1 200 ft. in length. In addition to the space required for the terminal station building, baggage, mail, and express facilities, there will be room within the area to create a mechanical terminal of sufficient capacity to care for steam and electric locomotives using the terminal and also for the storage of through-passenger equipment.

The easterly part of the through-passenger terminal at East Roosevelt Road will be completed and ready for service at the time the suburban service is electrified, leaving the present through-passenger station facilities for use under steam operation during reconstruction.

It is planned to develop the suburban area at Randolph Street, the local freight terminal at South Water Street, and the through passenger terminal at East Roosevelt Road, in such a manner as to make possible the complete development of the air rights over the entire area in accordance with the provisions of the zoning ordinance, passed by the City of Chicago on April 5, 1923.

From East Roosevelt Road south to 51st Street, a distance of about 5 miles, the right of way is nowhere less than 300 ft. wide, except from 31st to 41st Streets, where it is 250 ft. wide. From 51st Street to the southerly city limits, the right of way in all places is 200 ft. or more in width.

The general track arrangement where the right of way is 200 ft. wide is as follows:

1.—Construct two industrial switching tracks immediately adjoining the west side of the right of way.

2.—Construct four suburban passenger tracks with separate platforms for local and express service, adjoining the industrial tracks on the east.

3.—Construct four through passenger tracks, with platforms at stations it is necessary to serve, adjoining the suburban tracks on the east.

4.—Construct two through freight tracks and one industrial switching track adjoining the east side of the right of way.

In the territory where the full width of the 200-ft. right of way is developed with tracks and station platforms, it is proposed to construct the through and suburban passenger stations either above or beneath the tracks.

The main line south to the southerly city limits is practically all in track-elevation territory where the plane of the roadbed has been raised above the plane of the streets. Prior to the time the various services are electrified, it is planned to eliminate grade crossings of all kinds, whether across streets, highways, or other railroads, within the electrified zone.

Plans have been made to carry out the construction on a schedule which will meet the requirements of the ordinance, as follows:

1.—Complete the easterly side of the through passenger terminal; complete the re-arrangement of sewers and underground facilities; extend the track elevation and grade separation; make changes in grades that are necessitated by the ordinance; be prepared to proceed with the work of electrification; and electrify the entire suburban service within seven years after February, 1920.

2.—Electrify the entire freight service north of East Roosevelt Road within three years after the completion of the suburban electrification, or before 1930.

3.—Electrify the entire freight service south of East Roosevelt Road within five years thereafter, or before 1935.

4.—Electrify the through passenger service not later than 1940, if a certain proportion of the railroads using the lake-front passenger terminal station are operating electrically at that time.

The work of electrification contemplated in the ordinance embraces approximately 418 track miles. The electrification system to be used was determined by a commission appointed by the Railroad Company. This body made a careful study of the Chicago Terminal situation and compared it with the electrifications of similar properties in the United States and foreign countries. The Commission recommended, and the Illinois Central Railroad Company adopted, the 1 500-volt direct-current overhead-contact system for use in the Chicago Terminal Area. The details for the electrical system are being worked out, and it is planned to begin partial operation of the suburban service about the middle of 1926. The generation of current can be provided for readily either along the shore of Lake Michigan, Lake Calumet, or the Calumet River, adjoining the electrically operated tracks, and easily accessible to ample supplies of water.

For tractive power, high-tension alternating current, of probably 33 000 volts, will be converted to 1 500-volt direct current in not less than five substations on the Railroad Company's right of way. The conversion will be by rotating machines; the machines, transformers, switchboards, and auxiliary apparatus being housed in brick buildings of attractive design. The direct-current switching and protective equipment will be of the latest high-speed type.

The overhead system will consist of steel supports spaced approximately 300 ft. centers, for carrying the contact wires, transmission, signal, and miscellaneous power circuits. The overhead contact wires will be supported by messengers of high conductivity, so that over each track there will be sufficient conductor to supply the power required for that track, thus avoiding the necessity for independent parallel feeders. The contact wires, messengers, and their attachment will be made of materials highly resistive to corrosion. The normal height of the contact wire above top of rail will be 22 ft., and it will be suspended from the messenger so as to make its alignment conform to that of the track it serves. As the electrification will be carried out in progressive steps, the spans constructed initially for the suburban electrification will be ultimately extended to include the freight, through-passenger, and such subsidiary tracks as will be electrified. The track rails being well bonded will form a return circuit for the propulsion current and will be cross-bonded at impedance bond locations, thus avoiding any interference with signal-track circuits.

Suburban passenger cars are now being purchased for the electrified service, but are being placed temporarily in steam suburban service. The character of the suburban service is such as to make the multiple-unit train the most economical system. Provisions are being made for operating two-car semi-permanently connected units of one motor car and one trailer car. These units will have control apparatus in one end of each car and will operate either singly or in trains of two to five similar units. The service provides

for a high rate of acceleration and deceleration and a normal balancing speed of 57 miles per hour on tangent level track. The motor cars will be equipped with four 750-volt motors connected in two groups of two motors in series per group with series parallel control.

The braking equipment will be the electro-pneumatic brake for multiple-unit service with a 1 500-volt motor-driven compressor. Power for the control and brake operation as well as for the car lights will be furnished by a motor generator set on the motor car, having a 1 500-volt direct-current motor and a 32-volt direct-current generator with storage battery provided as a reserve. The two-car unit will have a pantograph collector on the motor car only. Electrical heaters will be used, the details of which have not as yet been fully decided.

The general dimensions and data that apply to the steel suburban cars either built or under purchase are as follows:

Length over buffers	72 ft. 7½ in.
" inside body	59 ft. 8¾ in.
" of vestibule	4 ft. 0 in.
Truck centers	47 ft. 9 in.
Width over eaves	9 ft. 11½ in.
" " platforms	10 ft. 6 in.
" inside body	9 ft. 1 in.
Height, top of rail to top of car	13 ft. 7/16 in.
" to center line of coupler	2 ft. 10½ in.
" inside car to lower deck	7 ft. 13/16 in.
" " " " clerestory	8 ft. 4⅛ in.
Weight of present cars light	92 200 lb.
Seats, cross-seats	34, 68 passengers
" , longitudinal seats	4, 16 "
Windows	42 main windows

The cars will be equipped with diaphragms enabling passengers to move safely and comfortably between cars and thus make advantageous use of all seats in the train. By the use of aluminum alloys and a careful re-design of the original steel suburban car, the weight will be reduced approximately 3 000 lb., reducing the trailer car to approximately 89 000 lb.

As there will be no need to purchase electric locomotives for either through main-line freight service or switching service, or for the through passenger service, for several years, no attempt will be made to design for such equipment at present.

CHICAGO TERMINAL IMPROVEMENTS, DEARBORN STATION GROUP

By Frederick E. Morrow,* Assoc. M. Am. Soc. C. E.

The Dearborn Station Terminal Group Development is still in the preliminary stage wherein the study of a development of the basic or general plan is being considered. Final details of arrangement of the various parts have not yet been completed, therefore, a discussion at this time must be limited to the development of the general plan and the fundamental considerations involved.

This terminal is one of the six large terminals in Chicago. Many plans and discussions have been offered regarding the consolidation of Chicago terminals on the theory that the needs of the city would be advanced thereby, the convenience of passengers increased, and economies effected for the railroad companies. Careful studies have shown that the needs of the city can be met best by proper planning of the terminal arrangements without drastic and far-reaching changes in railroad locations; that Chicago is mainly a terminal point for passengers; that there is relatively little through passenger business without stop-overs; and that the development of railroad transportation facilities in Chicago, which has resulted from a growth required to meet the needs as they arose, is a safer guide for planning the future than purely theoretical plans formulated oftentimes without comprehensive knowledge of all the vital requirements.

Location.—The Dearborn Station Group Terminal occupies the territory directly south of the central part of the Chicago Loop District. It is bounded in general by State Street on the east, Clark Street on the west, Polk Street on the north, and 16th Street on the south. The track approach to this terminal is from a southerly direction and, likewise, the railroads using this terminal approach the city from southeasterly, southerly, and southwesterly directions.

Use of Terminal.—The Dearborn Station Group Terminal was established in the early Eighties, the present passenger station being opened for business in 1885. The freight facilities have been constructed and enlarged from time to time as required. In the beginning, the terminal provided facilities for five railroads the business of which was not large. At present, facilities are provided in the passenger station for eight railroads and L. C. L. freight and team-track facilities for six railroads. The present normal passenger business averages about 125 trains per day and the freight facilities provide a track standing capacity of about 700 cars at freight-houses and 500 cars on team tracks.

Although local passenger traffic in this terminal is not as large as in some Chicago terminals, it cannot be disregarded and proper provision must be made for it.

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Problems to Be Met in Reconstruction.—The three main problems to be solved at this terminal are:

(1) To provide an arrangement which will enable the public streets to be opened so as to meet the public or civic need.

(2) To provide passenger and L. C. L. freight facilities to meet the present and future needs of the railroads.

(3) To provide a commercial or so-called air-right development which will produce a considerable income to reduce the burden on railroad transportation resulting from the large expenditure involved in a reconstruction project of this kind.

Public Street Development.—In studying the first problem, it is apparent immediately that street grades must be separated from railroad track grades, in order that streets may be opened both longitudinally and transversely in the area. Studies have indicated that the track grade should be below the street grades. Plans advanced by City authorities for straightening the Chicago River and for the street development in the area immediately west of this terminal, place the streets on an elevated plateau, with the railroad tracks slightly below the present street level.

Having in mind this general idea of the City authorities, plans have been formulated and given publicity recently, which will harmonize with this general scheme of the city for the territory west of this terminal. This plan places the elevation of passenger station tracks about 4 ft. below the present street level, and the tracks of the freight development from 4 to 14 ft. below that level. The main north and south streets, Dearborn and Clark, and the east and west streets across the terminal area are carried over the area on viaducts which connect with the present street grades at Polk Street on the north, State Street on the east, and the system of elevated streets planned for the area west of this terminal. These viaducts are planned with a view of providing liberal arteries for the through traffic, as well as the traffic local to the terminal.

Railroad Facilities.—In planning for facilities to meet the transportation needs of a terminal, a difficult and perplexing problem is presented. Although the growth of the traffic at a particular terminal, the growth of traffic over the country as a whole, and the growth of the particular city in the past, all furnish a guide for forecasting the future, many general economic changes may occur, which will largely nullify the most intelligent planning.

In recent years, the most pronounced growth has been in mail and express traffic, and in the length of passenger trains, rather than in the number of trains. In the past, the life of most stations has not exceeded thirty or forty years, and many have been cramped and crowded in certain facilities in much less time.

In providing for the future, it becomes a problem of prophesying not only what the growth of the traffic as a whole will be, but also the relative growth of the different parts, such as number of passengers, quantity of mail, express, L. C. L. freight and team track freight, length of trains, etc. Some parts may grow much faster than others, owing to general changes; for example,

only recently the development of the Parcel Post System has affected very radically the quantity of mail handled; the development of automobiles and improved highways have retarded the growth of railroad traffic in certain directions; the increase in private automobile ownership and the development of taxicab service have materially increased the demands on the vehicle loading and unloading facilities at passenger stations; and the width of driveways has been influenced by the development of long motor trucks. The future may bring further revolutionary changes. The improvements for this terminal have been planned in general for about 100% increase in capacity, with provision as far as possible for flexibility between the different parts as well as expansion in so far as it can be made without undue expense at this time.

The passenger station development has been arranged so that facilities and convenient access may be provided for the La Salle Street Station and Grand Central Station groups, if it is decided that such an arrangement is desirable.

Location of Passenger Terminal.—In the plans for the development of this terminal, the passenger terminal will remain at the present location on Polk Street, except that it will be enlarged to take the entire frontage between State and Clark Streets. This site was selected for the following reasons:

(1) It is within easy walking distance of the Loop District and the elevated trains, which is a very desirable feature for a large part of the passengers using the station.

(2) This site is readily accessible to passengers, by automobile and street cars, by three of the principal north and south streets leading south from the Loop.

(3) A study of the probable future developments of elevated and subway lines indicates that this locality will be increasingly accessible for the traveling public.

(4) The station and concourse can be placed at an elevation near that of the adjoining streets, an advantage for the ease and convenience of the traveling public in that vertical travel by stairways or ramps is largely avoided.

Location of Freight Facilities.—The L. C. L. freight-houses are situated south of the passenger station development between 12th and 16th Streets. The general plans provide for double level freight-houses, that is, tracks on the lower level and driveways on an upper level. The double level type is used in order to obtain greater capacity on the available area. Team tracks of necessity will be moved to another location.

Passenger Station Buildings.—The station building group consists of three modern office buildings of harmonious design and monumental effect through their size and grouping, thus producing a combination of architectural beauty and commercial utility without a large expenditure for purely architectural reasons.

The floor of the railroad station is essentially of the single level type and covers the street-level floor of the three terminal building units which open into

the main concourse. This concourse extends the entire length of the station, passing under Dearborn Street, and forms the main avenue for the movement of passengers to trains, waiting-rooms, and to all other facilities of the station.

Suburban traffic is confined largely to the State Street side of the station, thus avoiding the confusion which arises when suburban and through traffic are intermingled. Provision is made so that the suburban tracks may be looped under the station when the growth of traffic requires a very rapid handling of trains.

Air-Right Development.—The development contemplates an arrangement of all facilities and streets so as to permit a commercial development above the railroad facilities over the entire area, centralized about Dearborn Street as a north and south axis in which neither development will interfere with the other, but which in each case will contribute reciprocal advantages.

All this commercial development obviously would not be completed at the outset, but would begin with that over the passenger station and be enlarged and extended as the demand increased and as the surrounding district was improved. The development would be under centralized control and improvements contemplated would be limited to those suitable and attractive to the best class of commercial enterprises, such as office buildings, hotels, apartment houses, theatres, stores, etc. The possibilities of the growth of Chicago are unlimited, and it is believed that this district, if properly developed, will become very desirable.

In terminal development in large cities it is important to keep the cost of terminal facilities as low as possible consistent with proper service. It is believed that this can be accomplished best in this terminal by a proper air-right development which would carry a large part of the fixed charges on both the land and development cost of the railroad facilities.

CHICAGO TERMINAL IMPROVEMENTS, CHICAGO, ROCK ISLAND AND PACIFIC AND NEW YORK CENTRAL RAILWAYS

By Robert H. Ford,* Assoc. M. Am. Soc. C. E.

The authorities of the City of Chicago requested the railroad companies having terminals centering on the south side of the city, to co-operate in making terminal studies of this area, which might ultimately serve as an aid in its plan for future civic development. This section is immediately south of, and adjacent to, the so-called "Loop District", which is the heart of the intensively developed down-town business section of the city. On the east, it extends from State Street, four blocks from Lake Michigan, to Canal Street on the west, and to approximately Archer Avenue on the south, and comprises about 350 acres. The extreme westerly section, however, can be eliminated in this discussion, as it is now under consideration by the Chicago Union Station Company.

A considerable number of business houses and a variety of manufacturing and other industries are situated within this area, but it is principally occupied by the railway freight and passenger terminals of the so-called South Side railways, exclusive of those using the Illinois Central Terminal on the Lake front. The Chicago River, which is a navigable stream, flows through this section in a meandering course. The ultimate commercial importance of the Chicago River has been discussed for a number of years. The fact that the greater part of this section adjoins the Loop District, probably explains why it has been for years the favorite site for civic study by various individuals and bodies. Numerous plans have been advanced from time to time for its re-arrangement. It has been felt that if these areas could be properly co-ordinated and the network of streets and main arteries for municipal traffic extended, it not only would lessen the steadily increasing congestion of the central section of the city, but also serve as well to break down the southern barrier of the Loop District.

The location of the Chicago River has been one of the principal difficulties, it being generally agreed that any plan involving civic development or improvement within this area necessarily requires some form of re-location of the river, with which jurisdictional questions of Federal, State, and municipal rights, and to some extent, the Sanitary District of Chicago, are more or less involved. As the terminal facilities of a number of railway companies on both sides of the river would also be disrupted by this transfer, their co-operation was also necessary. The old river bed must also be subdivided and an adjustment effected in property lines and property rights. Although progress has been made through enabling legislation and otherwise, a definite conclusion on the problem of river straightening is yet to be reached.

It was especially in the furtherance of its efforts in this direction that the City authorities called on the railway companies using the Dearborn Street

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Station, with its head-house on Polk Street; those using the La Salle Street Station, on the border line of the Loop District, at Van Buren Street; and those operating the Grand Central Station, at Harrison Street, to undertake these terminal studies.

The railway companies using these stations may be referred to as the Dearborn Street, La Salle Street, and Grand Central groups, and are as follows:

Dearborn Street.—Santa Fé; Chicago, Indianapolis and Louisville; Wabash; Chicago and Eastern Illinois; Erie; Chesapeake and Ohio; Chicago and Western Indiana; and Belt Railway of Chicago, with about 18 000 miles of main lines.

La Salle Street.—Rock Island Lines, New York Central Lines, and the Nickel Plate System, with about 22 000 miles of main lines.

Grand Central.—Baltimore and Ohio, Pere Marquette, Great Western, and the Soo Line Railway, with about 13 000 miles of main lines.

The problem presents some relatively new and interesting features in railway terminal design because, among other things, this crooked river marks the boundary line of terminal facilities of important trunk-line carriers as clearly as the Connecticut River in New England defines the boundary line between the States of Vermont and New Hampshire. A straightened channel of uniform width within this section would cut off a considerable area belonging to, and being used by, several of the railway companies and assign it to others and alter, to a marked extent, present or future operation and development of the existing territory. It may also affect adjacent as well as other and more distant areas comprising other business, industrial, or residential sections.

Although some interesting and popular conclusions, have been advanced from earlier studies for civic planning in this locality, it has become increasingly evident that the interests of the city as well as those of the railway companies demanded an intensive study of these terminal areas, so extended and broadened as if, in fact, re-construction was actually imminent, before essential features could be determined in their proper relation to the future development of this great south portion of the city and their relation to Chicago as a whole.

Although the studies made thus far are in a preliminary stage, there are certain features which, in a general way, may perhaps be considered as guiding principles in a problem of this kind, namely:

1.—Railway terminals should be located within the central business district and in intimate contact with local transportation facilities.

2.—Railway terminals, although in a sense local in character, are, in fact, only a function of the transportation agencies of which they form a part.

3.—Municipal arteries of communication in and around terminal facilities should be ample and commodious, and designed with due regard to the future development and despatch of traffic in surrounding as well as in immediate areas.

4.—Terminal facilities in great cities should be planned with due allowance for an intensive development of air rights as well as the surface and sub-surface levels, in order that the expenditures involved do not become a burden on the transportation agencies.

5.—The warranted investment should be based on the expected life of the terminal and the service which will be rendered to the general public through the transportation system as a whole, as well as for the community it serves.

6.—Railway terminals being essentially distributing centers for a wide variety of service to the general public, their proper creation entails a well balanced design, for both present and future development, from the standpoint of civic, business, industrial, residential, and transportation requirements. For this reason, it is necessary that they be treated in a broad way, and that special recognition be given them by State and municipal legislative authorities in dealing with overhead and lateral clearances and municipal rights and franchises.

To these might well be added the following extract from the letter of Major Pierre L'Enfant to President George Washington in 1789, concerning the famous plan for the National City:

"Although the means now * * * are not such as to pursue this design to any great extent, it will be obvious that the plan should be drawn on such a scale as to leave room for that aggrandizement and embellishment which the increase * * * [in] wealth * * * will permit it to pursue at any period, however remote."

Chicago was a town of 4 000 inhabitants at the time of its incorporation in 1837; it is now the second city on the North American Continent, with a population of 2 850 000. Its transportation facilities, other than local, have increased from one railway, in 1848, to forty-five trunk-line, belt, and industrial railways, which, largely on account of the topography, enter the city from all directions, and all of which give service to the manufacturing and business districts which they traverse. Twenty-nine of these carriers engage in interstate passenger and freight service and compete for business originating within and without the so-called Chicago District.

The incorporated area of Chicago extends about 9 miles north and 16 miles south, respectively, from the central business section, the westerly line being 10 miles inland from the Lake, and comprises about 1 250 sq. miles.

Like other great cities, the dividing line for railway transportation is purely imaginary, but in Chicago there is an essential difference, because of the traffic problems necessarily introduced and the large number of railway service lines throughout this territory, around which center industrial and business areas more or less local in character. From these productive enterprises, shipments are made to and from all parts of the world, as well as throughout the vast network of industries included in what is known as the Chicago Switching District, comprising an area approximately 35 miles long and 25 miles wide, equivalent to about 875 sq. miles. Beyond this is the

Suburban Zone, the boundaries of which are not measured by distance, but rather by the time interval required to take passengers from the business district within a time limit of about 45 min.

Chicago is the greatest combined railway, industrial, and agricultural center in the world, and forms the dividing line between Eastern and Western United States, both with respect to manufacture and distribution, and its transportation problems are more varied and complex than those of any other city. An average of 1 250 passenger trains enter and depart from the city each day, and an average of 27 000 freight cars are moved, 4 000 of which are required to transact the present normal business of the down-town business district alone. Because of the currents and cross-currents of traffic influence, no proper development involving railway terminals can be considered from the standpoint of the huge investment of public and private funds involved, whether it is from a civic, industrial, or financial viewpoint, without careful and painstaking consideration being given to these features. Reference is made to this merely because these features are necessarily more or less involved in any economic study of the local railway terminal problems of Chicago.

One of the paramount features in such a study is an economic design for ample terminal facilities co-ordinated so as not to interfere with the proper development of municipal traffic or future commercial expansion. The possibilities of re-routing, co-ordination, or consolidation of facilities, multiple-level operation, and other relative features which may be essential to the improvement of any property of unusually high commercial value, must all be considered and developed to the extent of determining the relation of one to the other, as well as their effect on the immediate, adjacent, or other areas of the city and its environs. Multiple-level construction has been utilized in large cities for the purpose of a more intensive development for railway usage exclusively. The present congestion in the central business or Loop District of Chicago, however, requires that consideration be given to provisions for adequate facilities for the vast commercial interests in this vicinity, and to that end considerable pioneer work has been necessary. The Grand Central Terminal in New York City is illustrative of a solution of this problem in its relation to passenger facilities, and instances may also be cited to provisions having been made by commercial warehouses, stations, and railroad offices in connection with some of the later freight terminals.

Chicago's problem of expeditiously expanding its congested business district in connection with the handling (receiving, transferring, and forwarding) of more than 4 000 cars of L. C. L. business (package freight, less-than-carload lots) daily in the areas immediately adjacent to the central business district, is unique among the engineering projects of the world.

The business now handled in the area under study is divided into 26 units for inbound and outbound freight-house operation, with 13 team-track units, and has three passenger terminal stations located on an area of about 200 acres.

The Chicago Tunnel System, the construction of which was started about 1901, also taps this area. This facility is used for making package deliveries

throughout the down-town business district, and incidentally for relieving street congestion. It now comprises more than 60 miles of track of 2-ft. gauge, in tunnels having an average cross-section of 6 ft. in width, 7½ ft. in height, and 40 to 50 ft. below street level. This system is not extensively used, largely on account of the limited cross-section. The business handled through this tunnel relieves in some measure the street congestion originating at freight-houses, but, unfortunately, its limitations are such that a great expenditure would be necessary to make an increase in its capacity. In passing, it is interesting to note that these tunnels, although perhaps adequate for the purpose and the business then in contemplation, are of relatively little value as a means of affording any great relief to street congestion. Neither does the experience gained from a study of this and similar agencies tend to show that tunnel development for Chicago would be little more than a temporary expedient and one which, viewed in the light of probable future municipal traffic problems, may be an expenditure of doubtful ultimate value. Indeed, for present and future needs, with economy and adaptability in mind among other considerations, more serious thought should be given to some plan that will provide double-decking the central business areas in such a manner as to permit classification of the vastly increasing and diversified traffic, in order that it may not be unduly impeded and congested, and the intensively developed central areas suffer as a result of their partial isolation because of inability to obtain adequate street service.

In planning any re-construction of the area under study it has been assumed that main arteries and essential streets must necessarily be provided and placed on levels elevated above the lower or terminal track levels.

In the practical solution of the problem, it has been found that commercial and office buildings, hotels, etc., may be provided on all streets, to an extent not heretofore attempted, and that these newly arranged streets can be more intensively developed than heretofore has been the practice; also that freight-house facilities can be arranged so that the large amount of vehicular traffic which necessarily forms an integral part of freight-house operation, can be planned so as not to impede unduly the handling of general traffic on the main arteries or trafficways of the city. Service tracks for the business houses also may be arranged so as to eliminate much of the handling or re-handling of freight.

Street building may also be treated in a manner such as to permit the business development, in effect, to screen freight-houses or similar facilities, with the street frontage treated esthetically and in harmony with a civic plan for adjoining areas.

In studying any plan for terminal development in Chicago, in its relation to civic improvements, economies, and facility of railway transportation, due consideration must also be given to the waterways in and around the city.

The investigations which have been made in multiple-level development indicate great opportunities for more intensive use than heretofore has been considered in restricted areas of high commercial value for both railways and municipalities.

Although the studies essential to the proper solution of the problems centering around this South Side area—the subject of this paper—are incomplete, it is believed that they have been developed sufficiently to indicate with clearness the necessity of considerable modification of the earlier civic plans which limit this area to the development of freight facilities exclusively.

Engineers of the Rock Island, New York Central, and Baltimore and Ohio Railways have been making independent and collective studies with the object of utilizing for terminals the property that would be included on the easterly side of a straightened river channel, and these plans indicate that ample provision can also be made within the La Salle Street terminal location for railroads entering the Dearborn and Grand Central Terminals.

It has also become evident that it is to the best interests of Chicago that there should be at least one passenger terminal in addition to the two authorized by ordinance and already under reconstruction, placed so that the passenger terminal station buildings shall be centrally located and well within the business district. In this way, it will not be necessary for the intervening areas to be re-constructed prior to the time that such terminal properties become an integral part of the commercial district.

The great potential value of the La Salle Street Station facilities, when ultimately developed along such lines, can be readily imagined; furthermore, with lower levels for railway purposes and the upper stories for general commercial use, the location must be peculiarly attractive for the future business development of Chicago. Although the present La Salle Street Station Terminal is comparatively modern and will not require much modification for several years, the studies now in progress show great possibilities for the future expansion of the business district of the city in this zone, and the unusual opportunities offered by comprehensive studies of any great terminal problem at a considerable period ahead of the actual necessity for consummation.

THE CHICAGO UNION STATION DEVELOPMENT

By J. D'Esposito,* Esq.

The general principles governing the location, design, and construction of a modern passenger terminal are, for all practical purposes, the common property of the Engineering Profession. There is no general agreement among engineers on all matters involved in the creation of a large, modern passenger terminal, but, nevertheless, most of the great terminals recently built show a uniformity of conception and arrangement which bids fair to become a fixed type.

The claim is not made that the new Chicago Union Station is a radical departure from the accepted idea of a modern passenger terminal of its type; nevertheless, it is felt that this newest of stations, in the negotiations leading to its development, in the provisions made to meet its peculiar requirements, in the arrangement of a combined station and office building, and in the solution of the mail-handling problem, possesses many characteristics which invest the subject with distinctive interest.

The Chicago Union Station had to be co-ordinated with, and worked into, a city beautiful plan; it involved real estate transactions of the most complex nature; it necessitated the creation of new freight terminals for several railroads; it furnished the opportunity for the building of the first large railway mail terminal building in the United States; and made possible a station layout which, although placed below the general street level, owing to the limitations imposed by the site, is a one-level station in the full meaning of the word; that is, one in which the users find all the facilities of the station on one floor, and that, the track level floor.

The present station was built in 1880, at which time Chicago had a population of 500 000 people. Chicago now has a population of 3 000 000, and the railroads entering the station have grown to a corresponding extent.

The earliest plan contemplating the rebuilding of the station dates back to 1901, at which time less thought was being given to co-ordinating a passenger terminal with plans of city development than at present. The plan eventually adopted for the new Chicago Union Station was laid out in 1906, and did not coincide with the conception of railroad terminal arrangement and location as set forth by civic bodies and other well-meaning persons who had endeavored to solve the Chicago railway terminal problem. The railroad companies interested in the proposed improvement, having reached an agreement on the major elements involved in re-adjusting the facilities absorbed by the proposed re-arrangement, in the spring of 1913 applied to the Council of the City of Chicago for an ordinance covering every phase of the proposed improvement.

At that time, three suggested solutions of the Chicago terminal problem were prominently before the public: First, the so-called Delano plan, which located all passenger terminals south of 12th Street, now Roosevelt Road;

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second, the Chicago Beautiful Plan, which located a number of terminals west of the river above the street level in the block between Canal Street and Clinton Street; and the third plan, fathered by the architect, Mr. Jarvis Hunt, which proposed a single huge terminal for all the railroads entering Chicago to be located between State Street and the river, extending from Harrison Street to 12th Street.

Numerous suggestions were made by many others having various ends in view, but the three solutions mentioned were the only ones which had any elements of practicability and carried weight, by reason of their sponsors as well as through the advertising given to the projects by the local press over a long period. The project of the Union Station Company did not happen to coincide with any of the solutions mentioned, and it became necessary to find some means of convincing the City authorities as to the soundness of the railroad project, making such secondary changes as the demands of the situation required and the needs of the railroad companies would permit.

One of the most important and most complex elements of the problem was the necessity of providing new freight terminals for the Pennsylvania Railroad, the Chicago and Alton Railroad, and the Chicago, Burlington and Quincy Railroad, in order to make possible the construction of the proposed passenger terminal. Of the three problems, that of the Pennsylvania Freight Terminal was the most difficult, for the reason that the proposed passenger station layout absorbed all the space occupied by the old Pennsylvania freight facilities. With the Chicago and Alton Railroad, the problem, although not so large, was equally difficult, the Union Station layout absorbing more than 50% of the area of the Alton's freight terminal. In order to make good this loss, it was necessary to purchase all the land adjacent to its tracks east of Canal Street between Harrison Street and 16th Street, on which it was possible to rebuild freight terminals adequate for its needs.

The Pennsylvania Railroad Company at an early stage in the negotiations decided to re-locate its freight terminal in a district which, to that time, had been free of railroad encroachment, namely, the area between Van Buren and Polk Streets, Jefferson Street, and Desplaines Street, being approximately 300 ft. wide and 1 600 ft. long, and containing about 500 000 sq. ft. All this land, which was made up of hundreds of individual parcels, was quietly purchased before the plan was presented to the City authorities for enabling legislation. It was around this part of the project that the storm of disapproval broke loose and threatened to wreck the entire plan. It was found, for instance, that the Pennsylvania Freight Terminal would interfere with a proposed east and west street on a line of the present Congress Street as laid out in the Chicago Beautiful Plan, and it was also maintained that it would be unwise to permit railroad encroachment on a district which, heretofore, had been free of such detraction.

At about this time, a body of public spirited citizens, members of the City Club, engaged Bion J. Arnold, M. Am. Soc. C. E., to investigate and report on the general plan of terminal development for Chicago, having especially in view the proposed Union Station project and its relation to an

ideal solution. Simultaneously, the City Council engaged the services of the late John F. Wallace, Past-President, Am. Soc. C. E., for practically the same purpose.

The conclusions of Mr. Arnold's report were that the proposed passenger terminal at Adams Street might better be located about 1 200 ft. south, at Harrison Street. Mr. Arnold rejected the Pennsylvania Railroad Company's proposition for a freight terminal between Jefferson and Desplaines Streets, his view being that no additional freight property need be acquired by the railroad companies west of Canal Street and that such a development would be detrimental to the interests of the West Side. He further stated that if an ordinance were to be given to the Pennsylvania Railroad Company granting it the right to build a freight terminal in that locality, the approach tracks and the freight terminal tracks should be placed below the general street level and covered so as to make them unobjectionable from every standpoint.

The conclusions of Mr. Wallace were in favor of granting to the railroads the right to build the station as contemplated, his solution for the general terminal problem being to locate all the remaining passenger terminals, other than those of the Union Station and the Northwestern, in a station to be built at the Lake Front and 12th Street. Mr. Wallace reported adversely on the plan of grouping all the stations south of 12th Street, neither did he look with favor on the project of a single union station as proposed in the Hunt plan. In regard to the Pennsylvania Freight Terminal project, Mr. Wallace reported in favor of granting the necessary ordinance, but suggested that the approach tracks and the entire development be depressed in a manner similar to that suggested in Mr. Arnold's report. At this stage of the negotiations, the operating officers of the Pennsylvania Railroad Company decided not to accept the freight-house ordinance with the limitations imposed by the recommendation of the engineers' reports, and the whole subject of the Union Station improvement came to a standstill for the time being.

Following several months of more or less exasperating negotiation, it finally became possible to secure an ordinance authorizing the construction of a new passenger terminal, together with the necessary freight terminal, in the location and of a type as originally proposed by the railroad companies, with the exception that the original Pennsylvania Freight Terminal plan was abandoned entirely and a new location substituted immediately west of the Chicago River and south of Polk Street, substantially as recommended in the reports of Messrs. Arnold and Wallace. Internal negotiations between the railroad companies and negotiations subsequently with the City authorities required nearly three years to effect a satisfactory agreement.

Looking at the matter in retrospect, it is permissible to state that closer co-operation at a very early stage in the negotiations between the railroad companies and the City authorities would have simplified matters greatly and would have saved much time and expense to all parties concerned. As it turned out, the year lost in the negotiations with the City authorities in this one instance, was sufficient to delay the beginning of the work into the period

of the World War, with a resulting increase in the cost of construction and labor difficulties, together with inevitable delay in its completion.

The Chicago Union Station ordinance was approved by the Chicago City Council on March 23, 1914, and accepted by the railroad companies on September 23, 1914. Its principal provisions in the order of their importance can be classified, as follows:

1.—The creation of a district bounded by the Chicago River on the east, Canal Street on the west, Kinzie Street on the north, and 12th Street, now Roosevelt Road, on the south, within which district the railroads operating in the new station have the right to re-adjust their passenger and freight terminals in any manner not in conflict with the requirements and limitations set forth in the ordinance.

2.—The vacation of all the streets and alleys in the territory embraced by the limits mentioned, and the vacation of all the streets and alleys in an additional district bounded by the Chicago River, Canal Street, Roosevelt Road, and 16th Street, giving to the railroads using the station the right of re-arranging only their freight facilities in this second district.

3.—The railroad companies were granted the right to occupy the entire space under new viaducts to be built for all intersecting east and west streets, from the east line of Canal Street to the river.

4.—Rights were granted to the railroad companies to remove from the district just named, sewers and all other city improvements, so as to permit of the free and full use of the properties in question without interference.

On the other hand, the railroad companies were obligated:

1.—To pay a certain sum of money as a compensation for street vacation and other grants made by the City. ($2 686 558.92.)

2.—To rebuild at their own expense all the viaducts within the area noted of a type acceptable to the City, and perpetually to maintain them.

3.—To rebuild a sewer system outside the district in such a manner as to take care of the part of the sewer system removed from the railroad properties.

4.—To widen and rebuild Canal Street at a uniform grade from Washington Street to Roosevelt Road, without any compensation from the City other than the cost of the air rights over the 20-ft. strip required for street widening.

It was agreed in the ordinance that the railroad companies should build two bridges over the Chicago River, one at Monroe Street and another at Kinzie Street, deducting the cost of such bridges from the money due the City for street vacations.

The district affected by this grant within the limits of which all the existing structures, streets, and public facilities have been changed or are being changed is almost 100 acres in extent, 35 acres being required for the passenger terminal itself, the remainder being needed for the several freight terminals of the railroad companies, owners, or tenants of the Union Station. Within this

district thousands of individual parcels of land had to be secured, the most important being as follows: The plant of the Western Electric Company, south of Polk Street, 208 000 sq. ft.; the plant of the Illinois Tunnel Company, 223 000 sq. ft.; Corn Products Company, 227 000 sq. ft.; Baltimore and Ohio Chicago Terminal Company's parcel of 313 000 sq. ft.; two large warehouses of Marshall Field and Company, north of Polk Street; the power plant of the Commonwealth Edison Company at Harrison Street and the river; the warehouses of the Anheuser-Busch Brewing Company, south of Harrison Street; and the Butler Brothers warehouse, north of Washington Street.

Negotiations leading to the purchase of these properties were conducted simultaneously with the negotiations with the City of Chicago in regard to the ordinance, and in no instance was it necessary to resort to condemnation proceedings. In the case of the purchase of the warehouse from Butler Brothers, the owners preferred to receive their compensation in the form of a new warehouse to be erected by the Station Company at its sole cost and expense, in lieu of the warehouses taken over by it. This arrangement resulted in the Station Company undertaking and carrying out the obligation of building a warehouse of about 10 000 000 cu. ft., in accordance with plans and specifications previously agreed on between the Station Company and the owners.

The plan of station improvement as contemplated at that time consisted of the following units:

(*a*).—A low monumental building west of Canal Street, containing a general waiting room, ticket office, lunch rooms, rest rooms, and other related facilities.

(*b*).—A concourse and train gates east of Canal Street.

(*c*).—Two groups of stub-tracks, fourteen in the south end of the station and eleven in the north end, each pair of tracks being served by a common platform, this platform to be used by passengers and for baggage, mail, and express trucking.

(*d*).—A baggage room placed below the concourse, with a system of tunnels reaching the outer end of all platforms, with elevators at both ends of the platforms for lifting trucks and handling baggage, mail, and express.

(*e*).—A large express building situated east of the southern group of tracks in the approximate location of the present Railway Mail Building.

(*f*).—A mail unloading platform along the river between Jackson Boulevard and Adams Street, at the east end of the concourse.

The plans that are now being carried out depart from the original plan in the following particulars:

1.—The low monumental type of building west of Canal Street has been changed to a combined station and office building, 20 stories high, providing more than 500 000 sq. ft. of office space.

2.—The large express building, increased to twice its original size and modified to meet additional requirements, is now the Railway Mail

Building, the upper stories of which are leased to the U. S. Government for the classification of parcel-post matter.

3.—In addition to passenger platforms, separate platforms for handling baggage, mail, and express have been provided, alternating with the passenger platforms.

4.—The extensive system of tunnels under the station tracks and platforms has been eliminated, all the baggage platforms sloping directly into the baggage-room, thereby eliminating all the elevators for handling baggage trucks.

In working out the details of the Chicago Union Station Building, the fact has been kept in mind that modern passenger transportation on the railroads does not end with the arrival of the train in the station, but requires facilities for transferring passengers to either public or private automobiles so that they can continue to their final destination. With this end in view, the Union Station Building provides a system of cab-stands and driveways within the building capable of accommodating more than 100 cabs and laid out so as to make possible the loading and unloading of a large number of cabs simultaneously. All the cab-stand and cab-loading facilities are placed at the station floor level, which is the same as the track level.

In addition to the facilities noted, a separate stand for private vehicles, is provided along the driveway connecting Adams Street and Jackson Boulevard, also on railroad property, the intention being that patrons arriving at the station already supplied with their tickets will stop at this point and reach their trains very quickly without having to go through the head-house.

One of the most important problems at the resumption of building operations following the conclusion of the World War was that of making proper provisions for handling mail. After the introduction of the parcel-post service in 1917, it was obvious that the facilities as originally provided in the basement would prove inadequate to meet the changed conditions. The Federal Government was giving serious study to the entire mail situation in Chicago, and, in 1919, the Postmaster General appointed a committee of the Railway Mail Service, with Mr. William I. Denning, then Superintendent of that Service, as Chairman, to investigate and report on additional facilities and methods of operation. This Committee reached the conclusion that a site conveniently located for both railway mail cars and motor trucks should be obtained and a building erected of adequate dimensions in which to handle the mails, a very intensive application of mechanical handling apparatus being recommended in order to reduce operating costs. Protracted negotiations between the Railway Mail Service and the Union Station Company culminated in an agreement in December, 1920, whereby the Station Company should erect a new mail building and lease the six stories above track level to the Federal Government, the Station Company retaining the track-level story and basement for its own operations.

The site formerly proposed to be used for an express building, between Harrison and Van Buren Streets, and just east of the proposed station tracks, met all the requirements of the U. S. Government as to accessibility of railroad

tracks and the affording of tailboard space for motor trucks, and the building was erected on this site. The agreement of the Union Station Company with the Government provided for the building being erected and placed in service by December 16, 1922, and on December 1 of that year, the Station Company had completed construction and the Government proceeded to take possession.

The building is 796 ft., 5 in. long and 75 ft., 6 in. wide. Its total cubical content is 8 715 000 cu. ft. It is flanked on the east by a driveway 30 ft. wide. About 3 000 tons of mail per day are being handled at the building, about 60% thereof being handled by the railroads at the terminal as inbound and outbound mail. Outbound mail from other terminals is received at the north end of the tailboard space at driveway level and is deposited in chutes which deliver to track level or basement. This mail is then taken by tractors and trailers and raised to the tailboard space at the south end, where it is dispatched to other terminals. Inbound mail destined to the Post Office in the upper floors of the building is taken direct by elevator to these floors. The intervening tailboard space between the north end (used for outbound mail) and the south end (used for inbound mail) is devoted to the requirements of the Post Office, all parcel post being received there. This mail is wheeled across the floor in small trucks to conveying belts which carry it to the third floor. On arriving at the third floor, the mail is deposited on a feed belt from which it is taken off by sorters and placed on classification belts. The mail separated on the classification belts is transmitted through openings in the floor and over other belts to working tables on the second floor, and final separation and classification is made at these tables. Two inclined belts reaching the fourth floor also make primary classification similar to the belts reaching the third floor. After final classification, mail is dropped through chutes to belts below the ceilings, which lead to spirals leading to track level. More than 8 miles of conveyor belts were used in the installation.

The building is equipped with nine 6 ft. 6 in. by 17-ft. and five 6 ft. 6 in. by 18-ft. freight elevators. There is available on the driveway 580 ft. of clear tailboard, or sufficient for 60 vehicles at one time. When all the tracks are completed there will be capacity for 61 postal cars. A tunnel extending from the north end of the terminal to the basement of the concourse will afford connection with cars at the Union Station platform.

A noteworthy structural feature of the buildings is the 149 ft., 4½-in. steel truss weighing 365 tons, which carries the upper floor over a track entering the building at its west wall, at the south end.

The construction of the Chicago Union Station and its related facilities was delayed by World War conditions and was entirely suspended on that account for more than one year. Several strikes interfered with the work, the longest causing a suspension for nine months of all construction activity during 1916-17. The work was delayed again in 1921, when the decision was made to change the original plan to one providing for an office building. It now seems possible to complete the entire project by the end of 1924, providing the labor situation does not become more acute than at present and that no strikes or other labor disturbances develop.

MODERN RAIL AND WATER TERMINALS, WITH PARTICULAR REFERENCE TO THE SITUATION AT CHICAGO, ILLINOIS

By Rufus W. Putnam,* Esq.

Introductory

In considering rail and water terminals, the speaker feels that so many excellent treatises have been prepared on the subject that an attempt to improve or enlarge on them would be somewhat superfluous. He does not, however, believe that any specific port, such as Chicago, can be considered wisely without some preliminary discussion in the abstract of the factors entering into the design of terminals. Therefore, as a preface to the consideration of the concrete case, the subject will be discussed theoretically.

MacElwee has defined a port as a harbor to which terminal facilities have been added, and a harbor as a sheltered body of water of sufficient depth to enable a ship to find shelter from the storms of the high seas. With the permission of the authority quoted, these definitions will be considered to apply wherever the terms port and harbor appear in this paper.

The welfare of a large port or terminal is more than a matter of local significance. On the other hand, great quantities of commodities are consumed in a large city and terminal facilities should be provided in order to handle them. The consumption of coal at Chicago is estimated to be about 30 000 000 tons annually and efficient terminal facilities for handling that quantity of freight are well worth while. This, however, is of National importance only in so far as it affects the flow of commerce through the terminal.

In order to illustrate the National character of such a terminal assume Lake Michigan to rise overnight so as to inundate the country within a radius of 100 miles of Chicago. What would be the effect on the State, the Middle West, the Nation, and ultimately the entire world? Or, assume a foreign invader obtaining a foothold on the Eastern coast, and cutting off the ports of New York and Boston and the other manufacturing and commercial centers of the Middle Atlantic and New England States from the remainder of the country. Would the National scheme of things be undisturbed? These two calamities are not cited as possibilities, but merely to indicate the National significance of the great ports. Being of National importance, their welfare should receive the attention of the entire Nation.

Terminal development should not be left to the land or water carriers the actions of which are too often prompted by the exigencies of competition or considerations of local importance. These questions should be decided by municipalities or States under Federal guidance so that the State and National factors involved will be properly provided. It is not intended that the municipal, State, or Federal authorities necessarily should

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build or operate the terminals, but they should plan them and require future construction and operation to be in accord with a comprehensive plan which provides for as many eventualities as can be foreseen with any degree of exactitude.

The supremacy of a port is largely dependent on three factors: First, the tributary commerce, actual or potential; second, the size and accessibility of the harbor; third, the efficiency of its terminal facilities. Where the first exists it is generally possible, by engineering devices, to provide the second and third. The first depends on factors inherent in the physical structure and configuration of the surrounding country and on climatological conditions, none of which may be largely influenced by works of man. Mountain ranges may be crossed or tunneled in order to provide communication between the hinterland and the coast; it is possible by irrigation and other devices to make the soil fit for agriculture, but deposits of coal, ore, and other minerals cannot be produced artificially. A rich hinterland capable of supporting a large population and producing an excess of agricultural, mineral, or manufactured products is fundamental.

In stressing the fundamental character of a rich hinterland the importance of the other two factors which are vital to the supremacy of a port must not be overlooked. The failure to provide proper facilities constitutes the chief weakness of the present way of doing things. There are comparatively few stretches of our long coast line, which are not capable of being served by a prosperous hinterland. In general, the second consideration, that of having a commodious and accessible harbor, is well taken care of in the United States, but where natural harbors exist or where artificial harbors have been provided, it has been the popular belief that transfer operations would take care of themselves and it has been assumed by the general public that the supremacy of the port would naturally follow.

That this is not true is realized only by those who have taken the time to investigate conditions. In one sense the Port of New York might be said to have attained supremacy, in that it leads all the other ports of the United States in volume and value of imports and exports. Is it proper, however, to claim supremacy for a port in which it costs more to move bulk cargo 60 ft. back from the water-front by ordinary methods than to ship that same cargo to Rio de Janeiro after it is loaded?

Considerations Affecting the Design of a Terminal

Definitions

Practically every writer on the subject of ports and terminals has had to preface his remarks by defining the terms he proposes to use. This is due largely to the colloquial terminology used. No one seems to have originated a set of definitions that is of general application. It is proposed that the following terminology be used throughout this paper:

Harbor.—A sheltered body of water of depth sufficient to permit a ship to anchor therein in safety during storms.

Port.—A harbor provided with terminal facilities.

Dock.—Any shore accommodation for the use of ships.

Wharf.—A dock, without slips, parallel to the water-front.

Pier.—A dock at a considerable angle to the water-front constructed out into the stream or waterway.

Quay.—A dock consisting of a solid fill between bulkheads paralleled by slips excavated into the shore.

Slip.—An open water space between adjacent piers or quays.

The Influence of Physical Characteristics

In designing a terminal, its fundamental purpose must not be overlooked. Irrespective of character of freight or cargo, classes of carriers, and transfer agencies, the sole object of a terminal is to facilitate the transference of passengers and cargo between carriers where that is made necessary by the conditions of the journey. Line-haul efficiency, either by rail or water, has been highly developed. The task for the future is to ease the transfer between carriers or lines; this should be the one aim of the terminal engineer in the design of a terminal.

Few ports, if any, have been built to order. In general, it is not possible to use a templet with which developments of channels, piers, and wharves may be made to conform. The physical characteristics of the site have a great deal to do with the plans adopted and the methods of construction followed. The port planner and terminal engineer, although following certain precepts of general application, must rely largely on their ability to adapt local conditions so that the most favorable development may be realized.

The determination of the type of shore accommodation for ships that is best adapted to the physical characteristics of the site is one of the first steps in planning a terminal. Wharves are generally the most suitable type of construction along a river front, or elsewhere if the channel is narrow. Piers are suitable in places where excavation is difficult, where depths are not too great, and the fairway is of sufficient width to permit the encroachment. Quays are economical if land adjacent to the water-front is not too expensive and excavation is comparatively easy. All three types may be made equally efficient for the transfer of passengers or cargo. The quay and the pier permit a more intensive use of the water-front. The pier requires less ownership of valuable land than either the quay or wharf. For industrial harbors requiring more land area than water area, the quay is generally the best type of construction.

In foreign ports, the range of tides is an important consideration and often requires special construction, such as basins and locks. In this country, the tidal range is not great enough to have an important influence on the design of port or terminal facilities. An equally serious situation, however, is the fluctuation of levels of certain rivers that form a part of the inland waterway system of the United States. Variations as great as 60 ft. have been noted and average yearly variations are in excess of 30 ft. However, as neither tidal nor flood fluctuations enter into the problem at Chicago, it will suffice to mention them only.

It is no great handicap for a port to be situated at some distance from the sea. Even in restricted channels, transportation by water is considerably cheaper than by rail, and if, by eliminating an extra handling, or by making it possible to use a better harbor site, or by bringing the ocean carrier to the natural cross-roads of land highways, a port is located a distance inland, there is no reason why it should not thrive as far as its position with respect to the sea is concerned, provided the difficulties of maintaining the connecting channel are not too great.

Several well known ports of the United States are well inland, of which the following are examples: Baltimore, Md., 151 miles; Portland, Ore., 112 miles; New Orleans, La., 106 miles; and Philadelphia, Pa., 105 miles.

Some of the inland European ports are: Hamburg, Germany, 67 miles; London, England, 67 miles; Bordeaux, France, 60 miles; Manchester, England, 54½ miles; Bremen, Germany, 54 miles; and Antwerp, Belgium, 50 miles.

It is not necessary that the harbor site be very large, although ample anchorage space is desirable. This space may be in the form of a basin or a long wide channel connecting the port with the sea. If ports are developed so that intensive use is possible, relatively small dock space is necessary as compared with present American practice. Well equipped European quays average more than 1 500 tons of cargo per foot of quay per year. At New York City, the average is 150 tons. For a commerce of about 30 000 000 tons per year of a general character 30 000 ft. of well equipped docks would suffice if the annual rate were 1 000 tons per ft. Compare this to the total length of water-front in the following cities: New York City, 921 miles; Boston, Mass., 141 miles; Baltimore, Md., 120 miles; Seattle, Wash., 114 miles; and Chicago, Ill., 67 miles.

However, it must not be imagined that all this frontage is available or suitable for port-development purposes. These figures are quoted to illustrate the statement that there is little question but that there is enough available and suitable water-front at the principal ports for a very efficient port development.

In addition to providing sufficient water area for anchorage purposes and water frontage for dock purposes, a port site must also provide ample space for the land facilities, notably transit sheds, warehouses, open storage yards, and railroad connections and yards. There is no rule by which this land area may be determined as it depends on the kind of freight handled, the length of the navigation season, duration of crop periods, efficiency of rail service, and many other considerations, all of which must be determined for the particular problem. A fundamental requisite is, that this land area must be immediately adjacent to the improved water-front, and as near it as possible without the facilities thereon interfering with the service of the ocean carriers. Physical characteristics, therefore, influence the location of the harbor with respect to the sea, affect the kind of shore accommodation used, influence the extent of anchorage area, determine whether intensive use of port facilities is necessary, and affect the layout of the port as a whole.

Effect of Continuity and Diversity of Flow

In planning terminal developments, thought should be given to the characteristics of the stream of commerce that is passing or is expected to pass through the port. Continuity of flow may be disturbed or interrupted by seasonal variations in shipments of one or more commodities. Grain shipments may occur any time during the navigation season on the Great Lakes, but the average weekly shipments for late August and September are more than twice the average for the entire season. It is necessary, therefore, to plan terminal facilities for the handling of grain so that the excess of supply over consumption may be stored at the terminals along the route of shipment and released more regularly and more in accordance with the availability of carriers. With grain there is a regular demand and an irregular supply, with the carriers and terminal facilities acting as equalizers. The reverse is true of coal the demand for which fluctuates violently, whereas the supply is fairly regular.

Further complications are introduced when the port or terminal is unable to render all-year service. All American lake ports are closed to navigation during a part of the winter; some of the river ports are inaccessible during extremely dry seasons, although this handicap has been largely overcome in recent years. The seaport of Montreal, Que., Canada, is open for only a part of the year. However, with the aid of ice-breakers all the seaports of the United States are able to do an all-year business, so this particular complication does not affect them.

In order to provide for these various disturbances to the continuity of flow of commerce, storage facilities are necessary at one or more points along the routes of travel. These facilities should be as near as possible to the locus of greatest fluctuation in order to equalize the load on the carrier. For grain, the nearer the elevators to the farms the better for the carriers. For coal, the storage yards or sheds should be as near the consumer as possible.

Storage facilities for the purpose of equalizing differences of supply and demand are not all that are necessary to preserve continuity of flow. The journey of any commodity from source to ultimate consumer is composed of various stages. For exports, it is generally from truck to railroad, to vessel, to railroad, to truck. It is impossible to synchronize the movements of these different kinds of carriers. A railroad car is too valuable to justify its being held to be loaded directly from trucks as they arrive; nor is it economical to hold goods in trucks or cars until a sufficient supply has accumulated to complete the loading of a larger carrier. As a result, wherever a change in type of carrier is necessary, facilities suitable for the proper storage of the commodities handled must be provided.

The function of all carriers is to move goods or passengers and their use for storage purposes is generally an economic blunder. Continuity of flow, therefore, may be facilitated by making provision for storage wherever there is a change in the type of carrier or where it is necessary to adjust the difference between supply and demand.

A balanced and diversified flow is another factor of importance in port planning. It is impossible to equalize the flow of a commodity, such as coal, throughout the season so as to give every departing vessel a full cargo. However, if other commodities are handled, the seasonal fluctuations of which do not coincide with those of coal, carriers will be able to remove a load regardless of the season.

It is of equal importance that the inbound and outbound traffic shall balance. Carriers are then assured of a load both ways and as a result can quote lower rates. Montreal is handicapped by the preponderance of its outgoing grain cargoes. As a result, great quantities of Canadian grain take the more expensive land route to New York City where the load factor is not so one-sided, and foreign rates are lower.

A central electric generating station can produce power more economically when its load factor is high, that is, when the demand is diversified. This is also true of a terminal. If devoted exclusively to the grain business its facilities are operated to capacity for a short period of the year and then lie practically idle. If cotton, oil, coffee, coal, rubber, etc., in addition to the grain, are shipped, the large investment for channel and general port development will be worked continuously and more nearly to capacity. Diversity of flow is an asset to be sought and developed. It results in a busy port as well as busy shipping throughout the entire season.

The Significance of Character of Cargo or Freight

The kind of freight passing through a port is an important consideration in planning for efficiency. If large quantities of any one commodity are to be handled, experience has shown that specialization of terminals, terminal equipment, and carriers results in economy that may not be achieved otherwise. It is well, therefore, to determine the kind as well as the quantity of freight to be handled in order to provide the best possible arrangement of facilities.

Freight may be classified as regards its source and destination. Local freight is that which originates in the vicinity of a port or is destined for consumption or manufacture there. In cities, such as London, New York, or Chicago, the local freight is of so much importance to the welfare of the port and of such large proportions that it must be carefully considered in the terminal plans. The local population is generally interested more in the efficient handling of the local freight than in the through freight. The efficient handling of this local freight insures local support of port development. Local freight may be of a general kind, such as that which passes through the down-town freight-houses of a railroad or over the floor of a commercial transit shed. It also may be industrial, that is, originate at or be destined for industries situated on a siding or industrial canal.

Through freight is that which originates elsewhere and is destined elsewhere, but must pass through the terminal. It may be stored for a time at the terminal, but as long as it is ultimately reshipped, it may be classed as through freight and treated as such.

Freight may be classified also as to the method of handling or kind of special treatment necessary, and for certain purposes more or less essential to terminal planning, it is well to do so. Following this plan, there is:

General cargo....Standardized package, miscellaneous package.
Bulk cargo.....Coal, ore, grain, etc.
Perishables.....Fruits and vegetables.
Inflammables.....Oil, explosives.

Imports will require customs inspection; foodstuffs will require inspections to insure compliance with pure food laws; and immigrants, inspection by Public Health and Immigration officials. Freight coming under one or more of these classes will require special handling or treatment and should be planned for accordingly.

The Significance of Type of Carrier

The next step in the consideration of important factors in port planning is to investigate the types of carriers engaged in transporting goods. As the tendency has been to adapt the carrier to the highway, as many general types of carriers are found as there are highways. For railroads there are freight cars; for roadways, trucks; for inland waterways and canals, barges; and for lakes and ocean, sea-going vessels. This classification, however, is only general and wherever the shipment of large quantities of any one commodity has been involved, specialized carriers have resulted. Therefore, under the general classification of railroad cars, open flat-cars are used for hauling heavy machinery and building stone; gondolas for coal; stock cars for cattle, horses, hogs, and sheep; refrigerator cars for meats and fruits; tank cars for petroleum; and box cars for general merchandise.

Trucks are not as highly specialized, but even under that category there are dump-trucks for building and other bulk materials; tank trucks for gasoline and oils; and merchandise trucks for general freight.

Barges have become largely standardized because of the comparatively few commodities for which barge transportation is practicable. For bulk cargo, open-top bulk carriers are used. If general cargo is to be carried, a deck-house, affording protection to the cargo as well as more carrying space for the lighter material, is fitted to the bulk carrier. The tanker is about the only departure from this modern standardized barge.

Carriers on the Great Lakes and the ocean might be arranged into two classes, those which specialize in the passenger business but which carry freight as an accommodation and to complete the cargo, and those exclusively engaged in the freight business. The former arrive and depart on schedule, whereas the freighters stay in port until they are loaded. It is imperative that the schedules of passenger vessels be arranged so as to permit the complete discharge of the inbound cargo and the loading of as much outbound cargo as possible before departure. If the scheduled turn-around is short, very efficient terminal facilities are required.

The cargo space of the passenger vessels is adapted somewhat to the cargo to be expected at the ports of call, although little specialization is attempted,

but if, for example, the passenger vessel regularly travels the route of the banana trade, special attention is given to refrigerating apparatus. Specialization, however, among freighters is more general. The specialized bulk carrier engaged in the ore, grain, and coal business on the Great Lakes is an efficient example of the type. There are also tankers for petroleum and its products; fruiters for the fruit trade; and the more or less standardized ocean freighter which can carry almost any cargo that is not fluid. The combination vessel which is intended to carry ore or coal in one direction and petroleum the other, is an interesting recent development.

The characteristics of the general types of carriers must be known if a terminal is to be properly planned and equipped. Of the four—truck, railroad car, barge, and vessel—the truck is the most flexible for reaching any given point by land, whereas, by water, the barge ranks first.

As regards relative first cost, the following figures, although approximate because of the fluctuation of present market conditions, will indicate the proper order:

Truck	$500	to	$800	per ton	cargo	capacity
Vessel	75	to	125	"	"	"
Railroad car	40	to	60	"	"	"
Barge	20	to	35	"	"	"

These figures show the importance of keeping a truck or a vessel moving under load. This is largely true because the truck and vessel are self-propelled whereas the railroad car and barge are not. It is as important, however, to keep locomotives and towboats on the move as it is vessels and trucks. For purposes of comparison, it might be better to pro-rate the first costs of locomotives and towboats against those of cars and barges. Even if that is done, the same order results as follows:

Truck	$500	to	$800	per	cargo	ton
Vessel	75	to	125	"	"	"
Railroad car	55	to	75	"	"	"
Barge	40	to	55	"	"	"

The relative cost of haul per ton-mile is the next point to be considered. As in the case of first costs, figures should be used with caution. Furthermore, ton-mile costs are not always a criterion of economy, because, although they may favor one type of carrier, the difference in length of routes necessarily followed may more than offset the savings in unit costs:

Truck	$0.05	to	$0.25	per	ton-mile	
Railroad car	0.005	to	0.01	"	"	"
Vessel	0.001	to	0.003	"	"	"
Barge	0.0005	to	0.003	"	"	"

Interchange

Having outlined the classes of freight as regards source and destination, indicated the kinds requiring special treatment at a terminal, and having discussed the characteristics of the various carriers that may arrive at, or

depart from a port, it is necessary to consider the means provided for transferring, loading, rehandling, or otherwise assisting in passing freight through a port to its destination. The methods used for facilitating interchange or delivery are: Trucking, direct switching, belt-line switching, lightering, and car floating. For freight of local origin, they are generally used as indicated in Fig. 45. Freight of a local destination is handled by reversing the procedure. Through freight would be interchanged as indicated in Fig. 46.

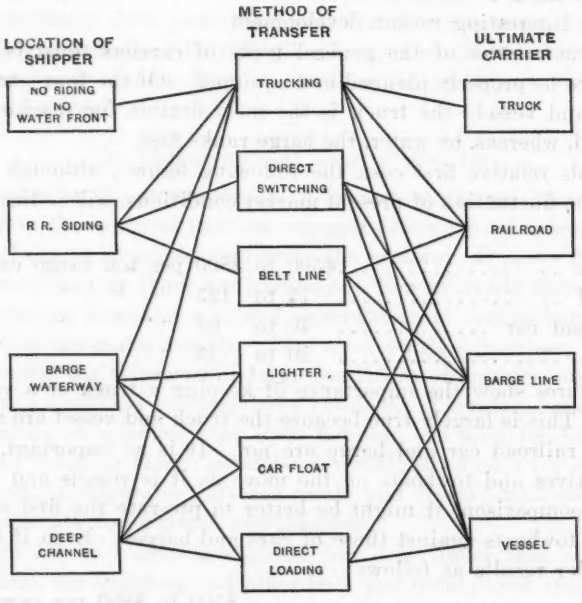


FIG. 45.

These diagrams only indicate the general methods used for interchange or delivery. In most cases, one or more handlings of the cargo are involved. True economy at a terminal is had when the number of handlings is reduced to the minimum, particularly with general miscellaneous cargo. General cargo, which is shipped in standardized packages, and bulk freight, may be re-handled at a fairly reasonable cost, but miscellaneous or perishable cargo costs so much to handle that the economies effected in the line haul are soon consumed at an inefficient terminal. Therefore, in selecting the method of transfer to fit any specific case, that method should be used which will require the least re-handling.

There is a point, however, beyond which elimination of re-handling is not economical. Carriers are now being built which will take on a cargo at Duluth, Minn., for delivery at New York City, without opening the hatches. Will the saving in transfer at Buffalo, N. Y., from 10 to 50 cents per ton, offset the loss occasioned by using a carrier on the Great Lakes that is not as economical to operate as the standard lake freighter? With fragile, per-

ishable freight it probably will, but for bulk cargo, such as ore and grain, it is problematical whether economy will result.

An Ideal Terminal

General Principles Involved

Port facilities are naturally divided into three categories, irrespective of the special character of the separate commodities that are handled through a port. There are those which make up the equipment of a commercial port, handling general cargo; those which are identified with an industrial port; and those which handle bulk cargo. There is a general type of layout and construction suitable for each, and each type may be adapted to the handling of the different commodities by the addition of the necessary appliances. Therefore, the details of cargo-handling devices will not be discussed, but only the general principles involved.

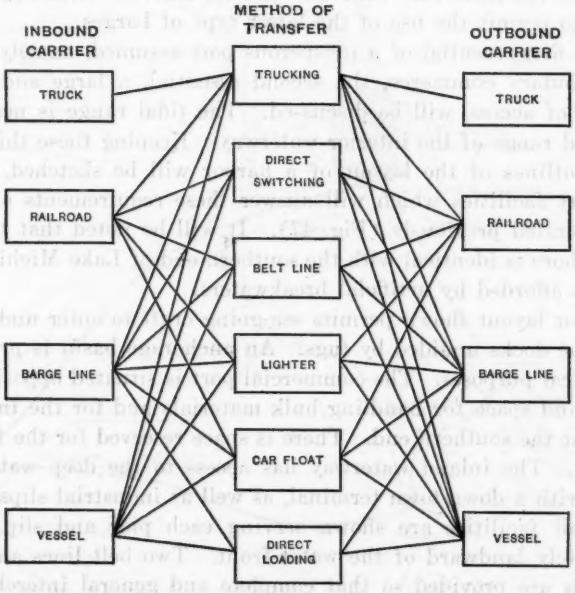


FIG. 46.

In planning the general layout of a port, the following considerations are of importance:

(*a*) The commercial port should be as near the center of the city as possible without creating too much congestion, because at a large port the local trade is of considerable importance and the task of carrying it to and from the terminals, which at best is quite onerous, is made easier by a convenient location of the port facilities. The miscellaneous character of general cargo results in a ship carrying local as well as through freight. A ship cannot engage profitably in retail delivery, so it should be able to discharge its cargo and take on a full load with only one berthing.

(*b*) Whatever type of dock construction is used, space should be available immediately landward for railroad yards of ample size for storage and classification purposes.

(*c*) Facilities for handling bulk cargo, for industrial port purposes, and for handling inflammables and explosives, should be located at the more remote parts of the harbor.

General Assumptions and Layout

For a working basis assume that at the ideal port accommodations of the three categories stated must be provided. Further, assume that the commerce will be of sufficient volume to justify the expenditures necessary in the application of the latest principles of port planning and in the use of the most modern types of structures. It will also be assumed that the port serves a hinterland which supports a balanced trade; that communication to the hinterland is by twelve main-line railroads and an interior waterway of sufficient dimensions to permit the use of the latest type of barges.

With the first essential of a prosperous port assumed, namely, a large and balanced tributary commerce, the second essential, a large and commodious harbor, easy of access, will be discussed. The tidal range is negligible, likewise the flood range of the interior waterway. Keeping these things in mind, the rough outlines of the layout of a harbor will be sketched, showing the principal port facilities which will answer these requirements as well as the others enumerated previously (Fig. 47). It will be noted that the configuration of the shore is identical with the southern end of Lake Michigan and that protection is afforded by artificial breakwaters.

The harbor layout shown permits sea-going craft to enter under steam and proceed to the docks unaided by tugs. An anchorage basin is provided ample for all practical purposes. The commercial port is situated opposite the center of the city, and space for handling bulk materials and for the industrial port is provided at the southern end. There is space reserved for the future expansion of each. The inland waterway has access to the deep water-front, and is provided with a down-town terminal, as well as industrial slips.

Ample rail facilities are shown serving each pier and slip. The yards are immediately landward of the water-front. Two belt lines and two classification yards are provided so that complete and general interchange is possible. Two union passenger stations and four union freight-houses are located down-town. Separate freight-houses are also provided. Where the belt lines intersect the main lines, suitable connections and yards are contemplated, but not shown.

Detail of Facilities

As previously explained, the function of a transit shed is to give protection to the cargo while it is awaiting the arrival of a vessel, or while it is being classified for re-consignment to the interior. In designing and locating a transit shed, the following considerations are involved:

(*a*) The shed should be parallel to, and 20 to 40 ft. from, the face of the dock on which it is placed.

(*b*) It should have width sufficient that the outgoing cargo may be stored opposite the berthing space occupied by a vessel, with enough vacant space to house the incoming cargo.

(*c*) Connections to land carriers, railroad and truck, must be adequate.

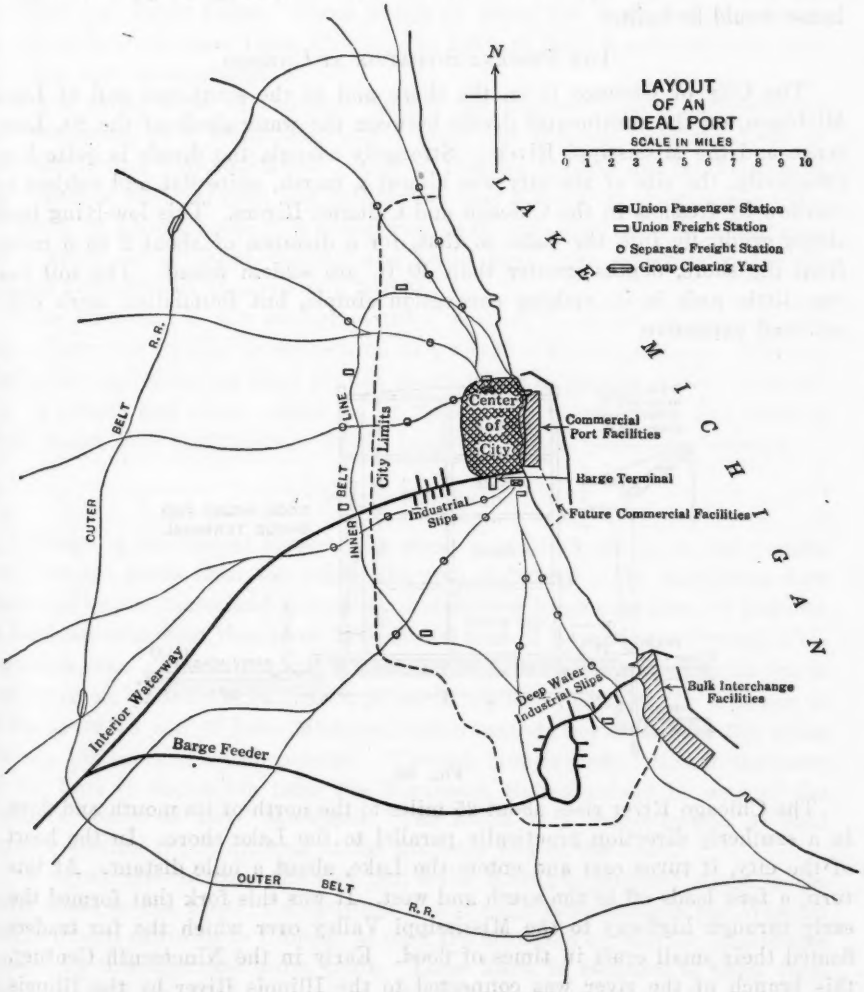


FIG. 47.

At the commercial docks will be transit sheds of the multiple-story type. For the purposes of this paper the structure will be used that was proposed by Capt. F. T. Chambers, U. S. N., M. Am. Soc. C. E., in his report on "Water Terminal and Transfer Facilities".* The slips for bulk carriers and at the industrial port are uniformly 400 ft. wide, although they are spaced at irregular intervals, the spacing depending on the character of shore facility

* House Doc. No. 109, 67th Cong., First Session.

or industry. For the down-town barge terminal, the type of shed shown in Fig. 48 will be used. Property values are high so that intensive use of the site is warranted. For down-town freight-houses, the kind built by the Pennsylvania Railroad Company at Chicago,* would be used wherever property values justified the expenditure. Otherwise, the Burlington type of freight-house would be built.†

The Present Situation at Chicago

The City of Chicago is on the shore and at the southwest end of Lake Michigan, on the continental divide between the water-sheds of the St. Lawrence and the Mississippi Rivers. Strangely enough, the divide is quite low. Originally, the site of the city was almost a marsh, quite flat and subject to overflow by freshets in the Chicago and Calumet Rivers. This low-lying land slopes gradually into the Lake so that, for a distance of about 2 to 3 miles from the shore, depths greater than 40 ft. are seldom found. The soil has very little rock in it, making excavation simple, but foundation work difficult and expensive.

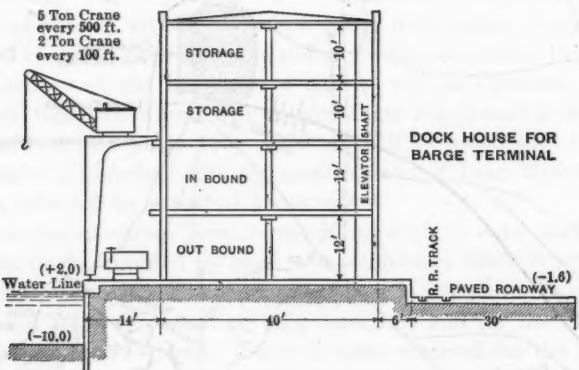


Fig. 48.

The Chicago River rises about 25 miles to the north of its mouth and flows in a southerly direction practically parallel to the Lake shore. In the heart of the city, it turns east and enters the Lake, about a mile distant. At this turn, a fork leads off to the south and west. It was this fork that formed the early through highway to the Mississippi Valley over which the fur traders floated their small craft in times of flood. Early in the Nineteenth Century, this branch of the river was connected to the Illinois River by the Illinois and Michigan Canal, and at the beginning of the Twentieth Century, the larger Drainage Canal was completed, carrying deep water as far inland as Joliet, Ill.

The Calumet River, rising in the State of Indiana and flowing west, then north, and then east, enters Lake Michigan at the southern end of the City of Chicago. This stream, like the Chicago River, has two branches, but the two

* See Fig. 62, p. 1594.

† Fig. 66, p. 1605.

branches of the Calumet River are practically parallel throughout their length. Connected to the Calumet River, about 6 miles from its mouth, is Lake Calumet, a shallow body of water about 2 200 acres in area, lying entirely within the city limits of Chicago. Outside the city limits, but of a similar character, are Wolf and Hyde Lakes. These bodies of water are more or less marshy, but are sufficiently near Lake Michigan to warrant their consideration in any plan for port development.

A few miles south of Calumet Harbor lies Indiana Harbor, an artificial port consisting of a breakwater and a canal cut through from the Lake to meet the Grand Calumet River. East of Indiana Harbor lies the Harbor of Gary, also an artificial port, and still farther east is the Port of Michigan City.

North of Chicago, the first commercial and industrial port is Waukegan, Wis., where an artificial channel and basin have been constructed by the Federal Government to serve as a harbor.

Lake Michigan is not subject to tides, nor are the rivers mentioned subject to large fluctuations in water level as a result of flood conditions. Natural conditions, therefore, are ideal for the construction of port facilities. Excavation is simple and cheap, there are no fluctuating water levels, and there is ample water area and frontage for all purposes if it is properly conserved.

Tributary Commerce

Chicago is the central market of a great area which produces and exports more surplus goods than any other like area elsewhere. The population now supported by the hinterland is capable of absorbing large quantities of imports. It has been estimated that about 200 000 000 tons of freight pass through Chicago each year. This hinterland is so remarkable in its present performance as well as in its potentialities that it is worth while to consider it. Chicago is at the southern end of Lake Michigan which extends northward for 300 miles through the heart of a rich country. Through land transportation to the ports of the East is impossible from the Northwest States, except by way of the southern shores of Lake Michigan. The result is a concentration of land carriers serving the Northwest at the southern end of the Lake.

Of equal importance is the fact that Lake Michigan provides access to the water route to the East. Competition in the early days brought the Western and Southern railroads to Chicago to meet the situation or reap the advantages created by this alternate water route. These lines, in addition to those from the Northwest, provided a service to all points west not enjoyed by any other city in the Middle West.

The existence of the all-water route to the East is also largely responsible for the efficiency and completeness of the rail service between Chicago and New York City. The competition offered by this route had to be met. In the early days of railroading, Chicago was selected as the western terminus of the Eastern Lines, for even at that time there was a concentration of existing routes of commerce at Chicago, including the old Illinois and Michigan Canal, which made it desirable for the roads to push that far West.

Chicago, therefore, became the railroad center of the Mississippi Valley, because all the lines, Eastern, Western, Northwestern, and Southern, made it their terminus. At present, about twenty-nine main lines enter the city. Each day approximately 27 000 cars pass in and out of the outer switching area more than half of them carrying through freight. Within the territory served by the roads terminating at Chicago, 70% of the country's wheat, 60% of the corn, 85% of the iron, 40% of the copper, and 46% of the lead, are produced. To the surplus agricultural and mineral products of the hinterland a constantly increasing quantity of manufactured goods must be added. The southern shore of Lake Michigan is rapidly becoming one of the most important industrial areas in the United States. Excellent railroad facilities have done much to attract large industries. Cheap water transportation between Chicago and the mines of Minnesota and Northern Michigan has stimulated the growth of steel and allied industries.

Within a radius of 400 miles and connected by excellent rail service are the cities of St. Louis, Mo., Milwaukee, Wis., Minneapolis, and St. Paul, Minn., Indianapolis, Ind., Detroit, Mich., and Cleveland, Ohio. These cities are all manufacturing centers of importance and contribute materially to the commerce passing through Chicago. The large agricultural population of the hinterland is capable of absorbing a correspondingly large quantity of imported goods, chiefly manufactures. The extensive industries in and about Chicago can use raw materials of all classes. Conditions are quite favorable for a balanced trade, an important factor in the welfare of a port.

It is not assumed that all the tremendous commerce of Chicago is for foreign trade. A large part is for consumption in the city. A great deal is of domestic origin or destination, but it would be fair to state that more than 30 000 000 tons per year has a foreign destination or origin under present conditions. It is difficult to state how large an increase might be expected, if a route for deep-draft vessels was opened to the sea.

Existing Water Transportation Facilities

The Harbor of Chicago is protected by a breakwater built by the Federal Government. This breakwater, which incloses an area of about 500 acres, extends from Oak Street on the north to Jackson Boulevard on the south. The harbor entrance is through a 500-ft. gap in the breakwater, about 1 mile offshore. This breakwater replaces the old structure off Grant Park that is now used to shelter yachts. Within the area are Harbor Districts Nos. 1 and 2, which were established by city ordinance under authority of the Cities, Towns and Villages Act of the State Legislature of 1911. Harbor District No. 1 embraces all the Chicago River, including the north and south branches, and also includes an area in Lake Michigan extending alongshore from the south side of the entrance to the Chicago River north to Chicago Avenue extended. Harbor District No. 2 embraces a submerged area in Lake Michigan extending along the shore from the south side of the Chicago River entrance to Randolph Street extended. The City of Chicago in exercising its

authority under the State law dedicated these Harbor Districts to harbor and commercial uses only.

At present, the U. S. Government maintains a channel 300 to 500 ft. wide from the entrance to the harbor to Michigan Boulevard Bridge for vessels drawing 21 ft. of water. Depths in the anchorage basin off the Municipal Pier vary from 16 to 24 ft., and alongside and leading up to the south side of the pier there is 20 ft. or more of water. Off Grant Park, the depths vary from 6 to 18 ft. In the Chicago River, the Federal Government maintains a channel 21 ft. deep, 200 to 300 ft. wide in the main branch, and 50 to 150 ft. wide in the north branch and North Branch Canal as far as North Avenue. Beyond North Avenue, the depths decrease so that not more than 14 ft. can be assured to the head of navigation at Belmont Avenue, the width varying from 50 to 100 ft.

The Sanitary District of Chicago maintains a channel about 26 ft. deep and from 90 to 150 ft. wide as far south as the entrance to the Drainage Canal at Robey Street. The Main Drainage Canal from Robey Street to Summit has a bottom width of 162 ft., from Summit to Willow Springs, the bottom width is 202 ft., and from Willow Springs to the power house, at Lockport, it is 161 ft. Depths in the Drainage Canal average 24 ft.

The South Fork of the Chicago River as far as Pershing Road is about 21 ft. deep over an average width of 50 ft. The two arms of the South Fork are being filled and abandoned gradually. This will also be done with the West Fork of the Chicago River west of Robey Street.

At the power house of the Sanitary District, at Lockport, is a navigation lock leading from the Drainage Canal to the Des Plaines River. This lock is 130 ft. long, 22 ft. wide, and will accommodate boats drawing 11 ft. of water. From this lock to the Illinois and Michigan Canal entrance at Joliet, about 2.3 miles, a 160-ft. channel has been provided with 12 ft. of water.

Navigation between Joliet and La Salle is by way of the Illinois and Michigan Canal, which at present will accommodate boats drawing 4 ft. of water, maximum length, 100 ft., beam, 16 ft., and height above water, 11 ft. 2 in.

From La Salle to Grafton, the route is *via* the improved Illinois River. Four locks and dams are used to improve depths and provide passage. Each lock is 350 ft. long and 75 ft. wide. In its present condition, the channel will accommodate boats drawing 6 ft. of water. In the Mississippi, the Federal Government maintains a channel 6 ft. deep between Grafton and the mouth of the Missouri River; from there to Cairo, the mouth of the Ohio, the depth maintained is 8 ft., and from there south to New Orleans, a 9-ft. depth is maintained. The Government is now completing a 9-ft. project for the Ohio River from Pittsburgh to Cairo.

On the Lake Front, between 16th and 31st Streets and about ½ mile offshore, the City of Chicago has established Harbor District No. 3 which will be reserved for harbor purposes in the future. It is lakeward of the park development now under way by the South Park Board.

The improvements at Calumet Harbor have resulted in a breakwater about 6 900 ft. long protecting an anchorage area of 424 acres in extent, which is maintained at a depth of 21 ft. The Calumet River has been widened, straightened, and deepened so that a channel 150 to 200 ft. wide exists throughout its length to the entrance to Lake Calumet and depths of 21 ft. are available to the General Chemical Company's wharf, and about 18 ft. from there to the "Forks", the head of navigation.

Harbor District No. 4 has been established in South Chicago by the City under authority of the State Legislature. It embraces all of the harbor and river in the State of Illinois and the proposed development in Lake Calumet. There are 55 bridges over the navigable parts of the Chicago River and its branches; and only 11 over that part of the Calumet River now under improvement. There is quite a current in the Chicago River due to the reversal of flow by the Sanitary District. In the Calumet River, there is practically no current, and although the Sanitary District proposes likewise to reverse its flow, it is not expected that the quantity of water withdrawn will be sufficient to cause an appreciable current.

The Calumet River is connected with the Main Drainage Canal of the Sanitary District by the so-called Sag Canal. Although this canal is 20 ft. deep, its width in rock (60 ft.) limits its usefulness as a waterway. However, it is capable of being enlarged and, if it is, it will be a valuable connection through which interchange bulk freight may pass to Lake vessels at South Chicago.

Rail Transportation Facilities

Chicago is the greatest railroad center in the world. The city is served by 23 separate carriers which operate 29 railroads. Within the city limits there are 16 independent belt or industrial lines, 80 or more points where freight is interchanged between roads, and 184 freight-houses, 69 of which are in the business district. There are 120 freight yards and 65 locomotive terminals. It has been stated that in the area bounded by the Indiana Harbor Belt Railroad and the Cities of Gary and Evanston, there are 12 982 tracks with a total length of 4 389 miles.

The average daily business in and out of the City of Chicago is:

Freight-houses	4 580	cars
Team tracks	1 630	"
Industries	6 027	"
Through business	14 488	"
Total	26 731	"

The total freight handled annually has been estimated to be between 175 000 000 and 225 000 000 tons.

The following separate carriers now serve Chicago: Atchison, Topeka and Santa Fé System, Baltimore and Ohio, Chesapeake and Ohio, Chicago and Alton, Chicago, Burlington and Quincy, Chicago and Eastern Illinois, Chicago Great Western, Chicago and Illinois Western, Chicago, Indianapolis and Louisville, Chicago, Milwaukee and St. Paul, Chicago and Northwestern,

Chicago, Rock Island and Pacific, Chicago and Western Indiana, Erie, Grand Trunk, Illinois Central, Michigan Central, Minneapolis, St. Paul and Sault Ste. Marie, New York Central, New York, Chicago and St. Louis, Pennsylvania, Pere Marquette, and Wabash.

The more important belt lines are: Elgin, Joliet and Eastern, Chicago Junction, Chicago River and Indiana, Baltimore and Ohio, Chicago Terminal, Belt Railway of Chicago, and Indiana Harbor Belt.

The Belt Railway Company of Chicago, which is owned by about twelve of the railroad lines entering the city, operates a large hump classification yard just outside of the city limits and south of 65th Street. The Belt Railway itself makes physical connection with practically all the main-line carriers entering the city. The yards are about 5 miles long and ½ mile wide, and contain approximately 180 miles of trackage. This clearing yard, in conjunction with the Belt Railway of Chicago, affords a quick medium of interchange of through freight as well as local freight. It is operated as a "hump" or gravity yard, the hump being at the gooseneck in the center. The yard layout is practically the same on each side, consisting of receiving and departure yards and classification tracks. Four tracks, two eastbound and two westbound, can be operated simultaneously over the hump. All switches in the classification yards are controlled by an electric pneumatic switchboard in the tower over the hump.

At present, about every conceivable means of interchange is used by the railroads at Chicago. From trucking of L. C. L. freight over the congested streets of the city between down-town freight-houses, to the efficient clearing of through traffic at the hump yard just described, there is hardly a method known to the business which is not in vogue, with the use of inefficient methods predominating. As a result, the average time spent in Chicago by a freight car, exclusive of train movements, has been estimated as 58 hours. Only a comprehensive uniform operation of facilities as a consolidated unit will improve conditions.

Conditions to be Planned for—Waterways

The full potentialities of any of the inland waterways have seldom been realized, but there are exceptions of which the enormous ore and grain traffic developed on the Great Lakes and the coal traffic on the Monongahela River are two notable examples. Moreover, the Ohio River and the Mississippi River will undoubtedly "come into their own" within the next few years, if the development of terminals continues at the present rate and the improvement of the Ohio is completed.

There is little encouragement, however, to be found in the present utilization of existing interior waterways or in the planning for future expansion. This condition is largely the result of the habits formed of shipping by rail. Only where a private corporation engages in a business requiring large shipments between a manufacturing establishment near a navigable waterway and a source of supply of raw material, or a market, is water transportation established, in which case it is a private affair, operated solely for the benefit of

the owner. The service provided for the less-than-carload-lot shipper or the general public is negligible.

It is being demonstrated that this is an unnecessary state of affairs by the service now rendered by the Federal Barge Line on the Lower Mississippi. This service is designed for the small as well as the large shipper. Arrangements have been made with connecting railroads so that through joint shipments may be made, and the experiment is proving to be successful for the operators as well as the users. The down-stream journey from St. Louis to New Orleans is made in seven days, equalling or bettering the time of rail shipments.

It is unfortunate that no detailed or complete study of the harbor requirements of Chicago has been made in recent years. A thorough survey of the situation was made by the Busse Harbor Commission in 1909, but on account of inadequate time and funds, the Commission had to confine itself to generalities. It was hoped by those sponsoring the legislation which led to the appointment of an Interstate Harbor Commission in 1921, to investigate and report on the feasibility of an interstate harbor south of Calumet Harbor and to consider details with respect to plans, estimated costs, proposed methods of development and management, estimated receipts, etc., that the Commission would consider the development carefully, as well as all correlated questions, such as plans for terminal facilities at Chicago, South Chicago, and elsewhere in this vicinity. Funds were provided to make a detailed study of the subject, but through a misconception of the intent of the legislation, the Commission failed to cover any more than the barest generalities so that its report is not of great value as a study of waterway terminal facilities at this end of Lake Michigan.

Before considering harbor facilities, thought must be given to the future. It is safe to assume that at some future time the St. Lawrence River will be improved so as to admit large ocean vessels to the Great Lakes. This development is bound to come, for even if the advantages to be obtained as a highway of foreign commerce cannot be visualized by those in a position to make the improvement possible, a demand will be created sooner or later for the development of the water power resources on the St. Lawrence, and in accomplishing this, it will be easy to provide facilites for navigation at the same time.

It also is safe to assume that in the near future a through barge waterway will be provided from Chicago to the Gulf of Mexico by way of the Drainage Canal, the Illinois Waterway and River, and the Mississippi River. With these two waterways completed and the existing channels maintained, Chicago will be in a position to engage in the following trade:

1.—Local lake traffic (coastwise and foreign).

2.—Lake and barge canal or lake and rail traffic to New York City (domestic and foreign).

3.—Foreign and Atlantic-coastwise trade by way of the St. Lawrence River.

4.—Domestic barge traffic (points on the Illinois, Mississippi, and Ohio Rivers).

5.—Foreign river-ocean traffic (transfer at New Orleans).

1.—Local Lake Traffic.—Local lake traffic will exist as it does now between Chicago and United States and Canadian ports. It will consist of bulk freight (ore, grain, oil, and coal), miscellaneous package freight, and passengers. Fruits and vegetables from Michigan and Wisconsin ports will be exchanged at Chicago for merchandise and manufactured products. The coal from Lake Erie ports will be exchanged for grain for export. The only change to be expected will be an increase in this traffic as a result of increased facilities afforded by the developments expected to result from the opening of the through waterways. If a proper adjustment of freight rates is made, Illinois coal may be transferred from barges to returning ore boats and compete at Duluth with Pennsylvania coal. In other instances, shortage of rail equipment will delay shipments between other cities on the Lakes, such as Cleveland and Detroit, and Chicago, so that considerable traffic will be forced to take the Lake route.

2.—Lake and Barge Canal or Lake and Rail Traffic to New York City.—A fair amount of commerce is now carried on between Chicago and Buffalo by lake. At Buffalo, transfer is made to barge or car and transshipment made to New York City. The New York State Barge Canal offers a water route to New York City from Buffalo and, if properly utilized, can compete successfully with the railroads. The bulk of this commerce at present consists in shipments of grain from elevators on the Chicago and Calumet Rivers. A very small quantity of package freight is handled. Considering the immense quantity of package freight that travels between New York City and Chicago each year by rail, it is believed that a considerable part should and would be handled by lake if proper service and facilities were provided. With the completion of the intra-coastal waterway along the Eastern coast it will be possible for barge fleets from the New York Barge Canal to reach Philadelphia, Boston, and Baltimore, and intermediate ports of less importance. Thus, opportunities will be afforded for Chicago merchandise to reach these ports by an all-water route.

Self-propelled cargo barges, of nearly the capacity of the locks of the New York Barge Canal, are being built to operate between New York City and Duluth, indicating that there are possibilities of developing craft that will operate economically and successfully on the Lakes as well as on the Canal.

3.—Foreign and Atlantic Coastwise Trade by Way of the St. Lawrence River.—Much has been said both for and against the improvement of the St. Lawrence River so as to permit deep-draft navigation between the Great Lakes and the ocean. Those opposed to the project affirm that ocean vessels would never enter the Great Lakes and if they did there would be little or no commerce for them. The supporters of the project picture great fleets of ocean carriers plying between Chicago, Detroit, and Cleveland and foreign ports, laden with the products of American soil or European industry. It would seem to a careful student that, as in most disputed questions, there is

a middle course which will be taken, its exact nature being difficult to predict, but the general features of which are of sufficient clarity to define them at present.

A glance at a list of commodities and manufactured articles shipped through, into, or out of Chicago, will indicate that between 20 000 000 and 50 000 000 tons have a foreign destination or origin and of this amount three-fourths is between Chicago and ports which could be reached more easily or economically by way of the Great Lakes-St. Lawrence route. There is no question but what there is sufficient foreign trade at Chicago to justify a careful consideration of the problem. To this foreign trade should be added a certain amount of Atlantic coastwise trade which is now carried by rail. It is safe to assume that of the traffic now centering at Chicago, from 20 000 000 to 30 000 000 tons would find the St. Lawrence route profitable. If account is taken of the increased trade which might develop as the result of giving Chicago access to the Atlantic by way of a deep-draft channel, this estimate would be materially increased. Whether it will be cheaper or more practicable for the specialized lake carrier to handle the traffic as far as Buffalo or Montreal and leave the remainder of the journey to an ocean carrier, than for the latter to make the through trip, is purely a matter of economy. The cost of transferring cargo is quite definite, and if that exceeds the saving effected by the use of specialized craft in lake or sea over the use of a vessel which can operate in either, then the latter method will result. There is little doubt but what either is a great improvement over the all-rail, lake-and-rail, or lake-and-barge canal routes.

It is difficult to state of what the over-seas traffic will consist. There will be a certain amount of passenger traffic. Large quantities of grain and food products and a certain amount of automobiles, agricultural machinery, and other manufactured goods will be moved eastward. Imports will include rubber, hemp, mahogany, clothing, manufactured articles of all kinds, and miscellaneous commodities not produced in this country. Exports probably will exceed imports in quantity, but not in value.

4.—Domestic Barge Traffic.—With the completion of the Illinois Waterway, a through route will be opened between Chicago and New Orleans for river barges of a modern type. In the light of recent experience by the Federal Barge Line on the Lower Mississippi, if adequately equipped terminals are provided at Chicago and other ports along the route, it is reasonable to expect that a considerable volume of commerce will develop. Large quantities of Illinois coal are used locally and for mines not too far from the waterway it should be possible to effect a considerable saving in freight rates by using the water route. St. Louis has a well equipped river terminal and will be able to send over the water route some of the merchandise that now moves to Chicago by rail. Chicago should be able to reciprocate by shipping manufactured products to St. Louis and other river ports. A large part of the grain produced within trucking distance of the Waterway should seek this route as well as live stock, building materials, and minerals. Eventually, the Waterway will have a capacity of 60 000 000 tons of commerce annually,

although with the locks on the Lower Illinois River in their present state, the capacity will be considerably less. The present domestic commerce between Chicago and points within easy reach of the Illinois and Mississippi Rivers may be expected to make a substantial contribution toward a healthy commerce on the Waterway.

5.—Foreign River-Ocean Traffic (Transfer at New Orleans).—The Illinois Waterway, besides providing a highway of domestic commerce between Chicago and river ports, will give Chicago an all-water route to the Gulf States and to South America. South America looked to Europe for her manufactured goods before the World War, but during the period of enforced suspension of exports from Europe, a thriving commerce developed with the United States, the continuance and growth of which is favored by the slow recovery of European finances and industry. South Americans have formed the habit of importing from the United States, and if the United States is alive to its opportunities, it will foster that habit and make it a custom.

The foreign and domestic commerce of the Port of New Orleans for 1921 amounted to about 15 000 000 tons. This was valued at $750 000 000. Most of it was through traffic and a large part was between New Orleans and South American or Gulf ports. The total foreign and domestic trade for all United States Gulf ports in 1921 amounted to about 50 000 000 tons with a valuation of about $2 500 000 000. Some of this trade originates at or is destined for Chicago. More of it will go to Chicago when cheaper transportation is provided to the seaboard. The imports include rubber, mahogany, hemp, oil, chemicals, and other raw materials from South American and Gulf countries. The exports consist chiefly of cotton, grain, and manufactured goods. The last especially should interest Chicago.

Railroads

No increase in the number of railroad lines entering the City of Chicago is to be expected, as the hinterland is quite thoroughly tapped by rail lines. Improvement in efficiency in line haul and improvement in terminal conditions will be the object of future development. Two large passenger terminals at Chicago are now under reconstruction, the Illinois Central Terminal and the Chicago Union Station, including the rebuilding of the downtown freight-houses of the lines involved. The South Side passenger stations are becoming antiquated; furthermore, they obstruct the city's growth to the south. Numerous plans have been presented for the re-vamping of these facilities, all of which have their merits, but none seems to be acceptable to all concerned.

To the speaker it seems that an equally important question is the proper consideration of the efficient handling of freight. The 58 hours lost by each freight car in transit through the City of Chicago would carry it 75 miles toward its destination, if the low daily movement of 30 miles, as estimated by some authorities, is assumed. Thirty miles per day is such a low figure for the average daily movement of a freight car as to warrant the most care-

ful investigation of conditions at the principal railroad centers. Fortunately for Chicago, the necessity for increased efficiency of terminals during the World War, and the ability of the Railroad Administration to operate terminals as it saw fit, regardless of ownership of facilities, pointed the way to a solution of the difficulty; a solution which has since been adopted and amplified by the Board of Economics and Engineering of the National Association of Owners of Railroad Securities, Incorporated. As this solution appears to be sound in its general aspects and as the speaker is ignorant of a better and is not qualified to present one of his own, with the permission of the Association referred to, it will be assumed that any changes or future developments of importance in the field of freight terminal construction will be along the general lines recommended in the report of the Board.

The proposed operation of the system is outlined in the following extract from its report:

"The plan of the Board is to divert all through business around the city. All cars into and out of Chicago are to be collected in group yards along the Elgin, Joliet and Eastern Railroad which is to be used as an outer belt. It is proposed to eliminate all interchange points of which there are 80 shown in the Equipment Register; to eliminate transfer and connecting railways; to eliminate all freight yard and equipment facilities not needed for switching and passenger service. All through cars are to be transferred from group yard to group yard, and all improvements are to be made along this outer belt where they may be considered permanent until, after many years, the city's growth again requires a re-arrangement.

"It is proposed to use the Indiana Harbor Belt Railroad as a temporary belt line for transferring from the southeasterly group to the northerly group until it becomes necessary to devote it to other purposes on account of the growth of the city. There is no group yard provided at present north of Joliet for the reason that all existing railway yards are so located that they can be used conveniently. Eventually a group yard should be constructed at West Chicago, but no provision for it has been made in the estimate, and all estimates of savings are based on the use of individual yards north of Aurora as at present, except that the Illinois Central and the Chicago Great Western will use the Chicago and Northwestern yard at Proviso.

"The group yards will be four in number, located at or in the neighborhood of Porter, Griffith, Chicago Heights, and Joliet, * * *

"All freight terminals and service facilities except those required for the forces employed in the local switching service will be located in the group yards.

"There will remain in the city only such freight terminals and service facilities as are required for business of Chicago origin and destination. All other freight will be by-passed around Chicago by means of the group yards and outer belt lines. In the group yards all freight interchanges between roads will be made; all freight trains to and from the city will terminate there.

"Normally, the movement between group yards will be in full trains, and generally cars will be made up in full trains for the receiving road. So also will the city business leave a group yard in full trains for distribution after delivery to an industrial switching yard, and the make up of trains leaving an industrial yard can readily be made so as to require the minimum of switching after delivery to group yard.

"Each group yard will have transfer platforms where all L. C. L. cars may be consolidated for the city and for foreign lines. * * *"

The Approximation of the Ideal

Based on principles of port and terminal development, explained previously, the speaker attempted to plan the layout of an ideal port and described its general appurtenances. Having described conditions as they now exist in Chicago and as they might be expected to exist in the not too distant future, the speaker will now attempt to indicate how local developments may be guided so that, in time, and when needed, port facilities will be available which will closely approximate the ideal layout previously described.

In planning a layout for the Port of Chicago in accordance with what has been discussed previously, the following assumptions will be made, but many years will be required for the growth of the commerce of the Port of Chicago to reach these figures under the most favorable conditions.

1.—Access to the sea for deep-draft vessels will be available by way of the St. Lawrence River,

2.—An inland waterway permitting the use of modern barges will connect Chicago with the Mississippi River,

3.—The Chicago River will be closed to lake vessels.

4.—Commerce will be as follows, expressed in tons per year:

Local inbound rail	60 000 000
Through inbound rail	70 000 000
Local outbound rail	50 000 000
Through outbound rail	60 000 000
Interchange between lake and rail:	
General cargo	12 000 000
Bulk cargo	20 000 000
Interchange between inland waterway and rail:	
General cargo	1 000 000
Bulk	1 000 000
Interchange between inland waterway and lake:	
General cargo	1 500 000
Bulk	2 500 000
Local lake, general	7 000 000
Local lake, bulk	1 000 000
Local inland waterway, general	2 000 000
Local inland waterway, bulk	2 000 000
Industrial lake	16 000 000
Industrial inland waterway	2 000 000
Making a total commerce of:	
Rail	240 000 000
Lake	60 000 000
Inland waterway	12 000 000

5.—Railroad freight will be handled as recommended by the Board of Economics and Engineering of the National Association of Owners of Railroad Securities, Incorporated, in its report on Joint Terminals at Chicago of March 28, 1922.

Lake Traffic

It has been assumed that the Lake traffic will amount to 60 000 000 tons. Of this, 20 500 000 tons consists of general cargo to be handled at a commercial port, 23 500 000 tons is bulk freight and 16 000 000 tons is industrial. Following the previous line of reasoning, the general cargo of the commercial port should be handled as near the commercial center of the city as possible. There are three sites for the commercial port which fulfill this condition, but only one of these is of sufficient area or can be provided with ample railroad connections and facilities to handle all the commerce of this character. These sites are:

1.—The Lake part of Harbor District No. 1 (see Fig. 49): This is enclosed by a Government breakwater and includes the Municipal Pier within its area. About $7 500 000 has already been expended here. Railroad connections are by one line, the Chicago and Northwestern Railroad, or might be made by car ferry.

2.—Harbor District No. 2: A submerged area in Lake Michigan extending along the shore from the south side of the Chicago River to Randolph Street extended (see Fig. 49). This area is likewise protected by an existing breakwater. Direct railroad connections are limited to the Illinois Central and Michigan Central.

3.—Harbor District No. 3: A submerged area about ½ mile offshore between 16th Street and 31st Street extended. No harbor structures exist here, nor are there rail or highway connections, although the Lake Front Ordinance, which is a tri-partite agreement between the City of Chicago, the South Park Commissioners, and the Illinois Central Railroad, makes provision for the future construction of adequate approaches should they be necessary.

Having in mind, therefore, existing conditions as regards breakwatered areas, harbor facilities, rail connections, and the like, it is proposed that the 20 500 000 tons of general commerce per year be handled at Harbor Districts Nos. 1 and 3, beginning with the development of the former as it can be made use of with the expenditure of a comparatively small sum. Harbor District No. 1 should be used as much as possible for local cargo, as facilities for direct interchange between lake and rail are limited in capacity.

The Municipal Pier, with a few minor alterations of railroad and street connections, and with the addition of cargo-handling devices can be made to handle about 2 000 000 tons per year. There is space to the north and south for four more piers of similar dimensions, but in view of the limited rail and highway connections it would be unwise to build all of them. One pier supporting a combination transit shed and warehouse of the approved design, located to the north of the Municipal Pier and 3 000 ft. in length, would handle about 3 000 000 tons per year. Storage space for goods handled at the Municipal Pier, as well as the necessary railroad yards, would be provided in the area immediately landward of the pier. Interchange between rail and lake will be by direct connection to the tracks of the Chicago and North-

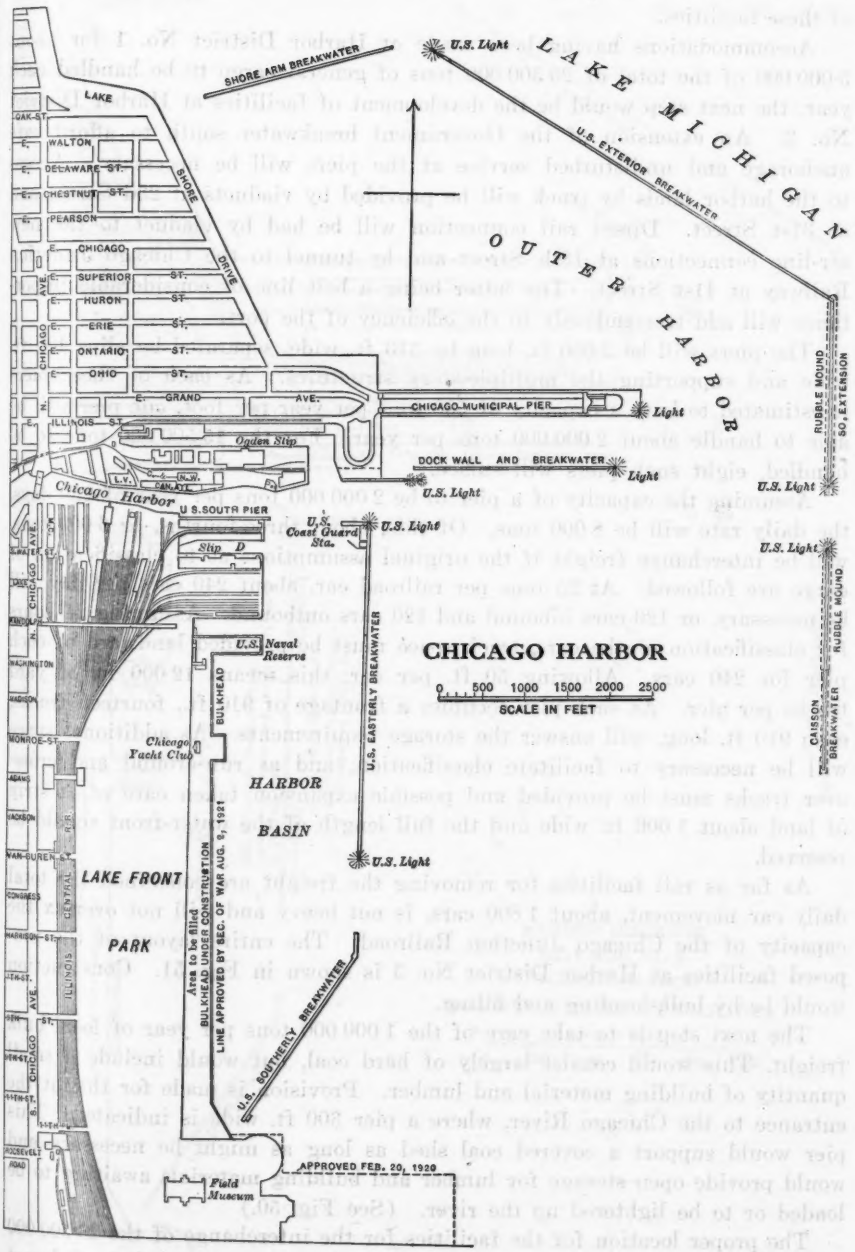

LAKE MICHIGAN
OUTER HARBOR
SHORE ARM BREAKWATER
U.S. Light
U.S. EXTERIOR BREAKWATER
RUBBLE MOUND
50' EXTENSION
LAKE
SHORE DRIVE
OAK ST.
WALTON
DELAWARE ST.
CHESTNUT ST.
PEARSON
CHICAGO
SUPERIOR ST.
HURON ST.
ERIE ST.
ONTARIO ST.
OHIO ST.
GRAND AVE.
ILLINOIS ST.
CHICAGO MUNICIPAL PIER
Light
Ogden Slip
DOCK WALL AND BREAKWATER
Chicago Harbor
U.S. SOUTH PIER
U.S. Coast Guard Sta.
Slip D
CHICAGO HARBOR
0 500 1000 1500 2000 2500
SCALE IN FEET
U.S. Naval Reserve
BULKHEAD
U.S. EASTERLY BREAKWATER
Chicago Yacht Club
HARBOR
BASIN
LAKE FRONT
PARK
CENTRAL R.R.
ILLINOIS
CAISSON
BREAKWATER
Area to be filled
BULKHEAD LINE APPROVED BY SEC. OF WAR AUG. 9, 1921
U.S. SOUTHERLY BREAKWATER
APPROVED FEB. 20, 1920
Field Museum

FIG. 49.

western Railroad, and by car ferry. Fig. 50 shows the general arrangement of these facilities.

Accommodations having been made at Harbor District No. 1 for about 5 000 000 of the total of 20 500 000 tons of general cargo to be handled each year, the next step would be the development of facilities at Harbor District No. 3. An extension of the Government breakwater south to afford safe anchorage and undisturbed service at the piers will be necessary. Access to the harbor lands by truck will be provided by viaducts at 23d Street and at 31st Street. Direct rail connection will be had by viaduct to the new air-line connections at 18th Street and by tunnel to the Chicago Junction Railway at 41st Street. The latter being a belt line of considerable importance will add tremendously to the efficiency of the port.

The piers will be 2 000 ft. long by 510 ft. wide, separated by slips 400 ft. wide and supporting the multiple-story structures. As each of these piers is estimated to have a capacity of 500 tons per year per foot, one pier will be able to handle about 2 000 000 tons per year. For the 15 500 000 tons to be handled, eight such piers will suffice.

Assuming the capacity of a pier to be 2 000 000 tons per year of 250 days, the daily rate will be 8 000 tons. Of this, about three-fourths, or 6 000 tons, will be interchange freight if the original assumptions as to classification of cargo are followed. At 25 tons per railroad car, about 240 cars per day will be necessary, or 120 cars inbound and 120 cars outbound. Assuming 24 hours for classification of the cars, track space must be provided landward of each pier for 240 cars. Allowing 50 ft. per car, this means 12 000 ft. of yard tracks per pier. As each pier occupies a frontage of 910 ft., fourteen tracks, each 910 ft. long, will answer the storage requirements. As additional space will be necessary to facilitate classification, and as run-around and cross-over tracks must be provided and possible expansion taken care of, a strip of land about 1 000 ft. wide and the full length of the water-front should be reserved.

As far as rail facilities for removing the freight are concerned the total daily car movement, about 1 800 cars, is not heavy and will not overtax the capacity of the Chicago Junction Railroad. The entire layout of the proposed facilities at Harbor District No. 3 is shown in Fig. 51. Construction would be by bulk-heading and filling.

The next step is to take care of the 1 000 000 tons per year of local bulk freight. This would consist largely of hard coal, but would include a small quantity of building material and lumber. Provision is made for this at the entrance to the Chicago River, where a pier 300 ft. wide is indicated. This pier would support a covered coal shed as long as might be necessary and would provide open storage for lumber and building materials awaiting to be loaded or to be lightered up the river. (See Fig. 50.)

The proper location for the facilities for the interchange of the 23 500 000 tons of bulk freight is on the Lake front south of the mouth of the Calumet River. No improvements have been made to the site, but in view of the wide, shallow foreshore, improvements by bulk heading, dredging, and filling

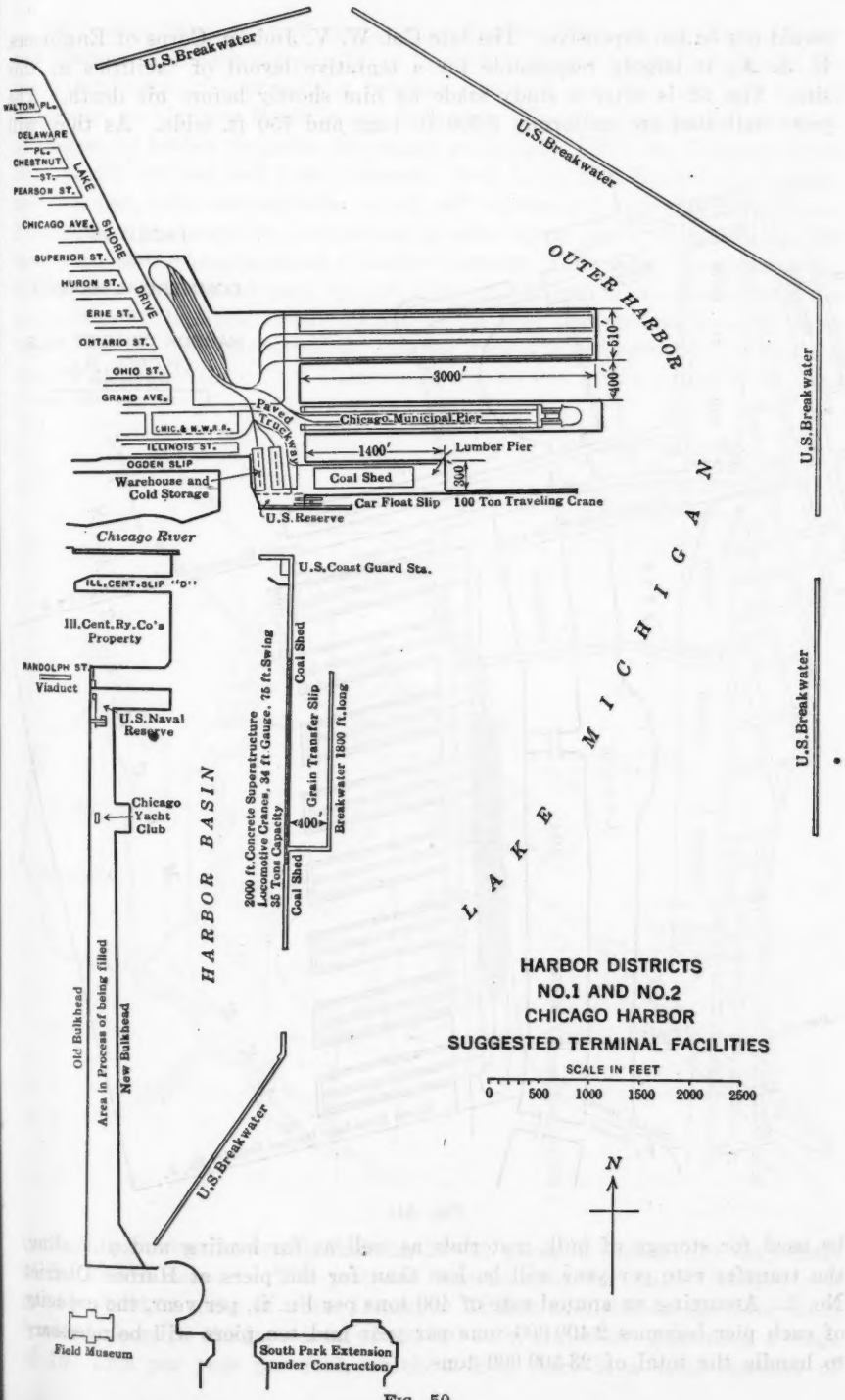

U.S. Breakwater
U.S. Breakwater
WALTON PL.
DELAWARE PL.
CHESTNUT ST.
PEARSON ST.
CHICAGO AVE.
SUPERIOR ST.
HURON ST.
ERIE ST.
ONTARIO ST.
OHIO ST.
GRAND AVE.
LAKE SHORE DRIVE
OUTER HARBOR
610'
400'
3000'
Chicago Municipal Pier
Paved Crosswalk
CHIC. & N.W.R.R.
ILLINOIS ST.
1400'
Lumber Pier
OGDEN SLIP
Coal Shed
300'
Warehouse and Cold Storage
Car Float Slip
100 Ton Traveling Crane
U.S. Reserve
U.S. Breakwater
Chicago River
U.S. Coast Guard Sta.
ILL. CENT. SLIP "D"
Ill. Cent. Ry. Co's Property
RANDOLPH ST.
Viaduct
U.S. Naval Reserve
Chicago Yacht Club
HARBOR BASIN
2000 ft. Concrete Superstructure
Locomotive Cranes, 34 ft. Gauge, 75 ft. Swing
35 Tons Capacity
Coal Shed
Grain Transfer Slip
400'
Breakwater 1800 ft. long
Coal Shed
LAKE MICHIGAN
U.S. Breakwater
Old Bulkhead
Area in Process of being filled
New Bulkhead
U.S. Breakwater
Field Museum
South Park Extension under Construction
HARBOR DISTRICTS
NO. 1 AND NO. 2
CHICAGO HARBOR
SUGGESTED TERMINAL FACILITIES
SCALE IN FEET
0 500 1000 1500 2000 2500
N

FIG. 50.

would not be too expensive. The late Col. W. V. Judson, Corps of Engineers, U. S. A., is largely responsible for a tentative layout of facilities at this site. Fig. 52 is after a study made by him shortly before his death. The piers indicated are uniformly 3 000 ft. long and 750 ft. wide. As they will

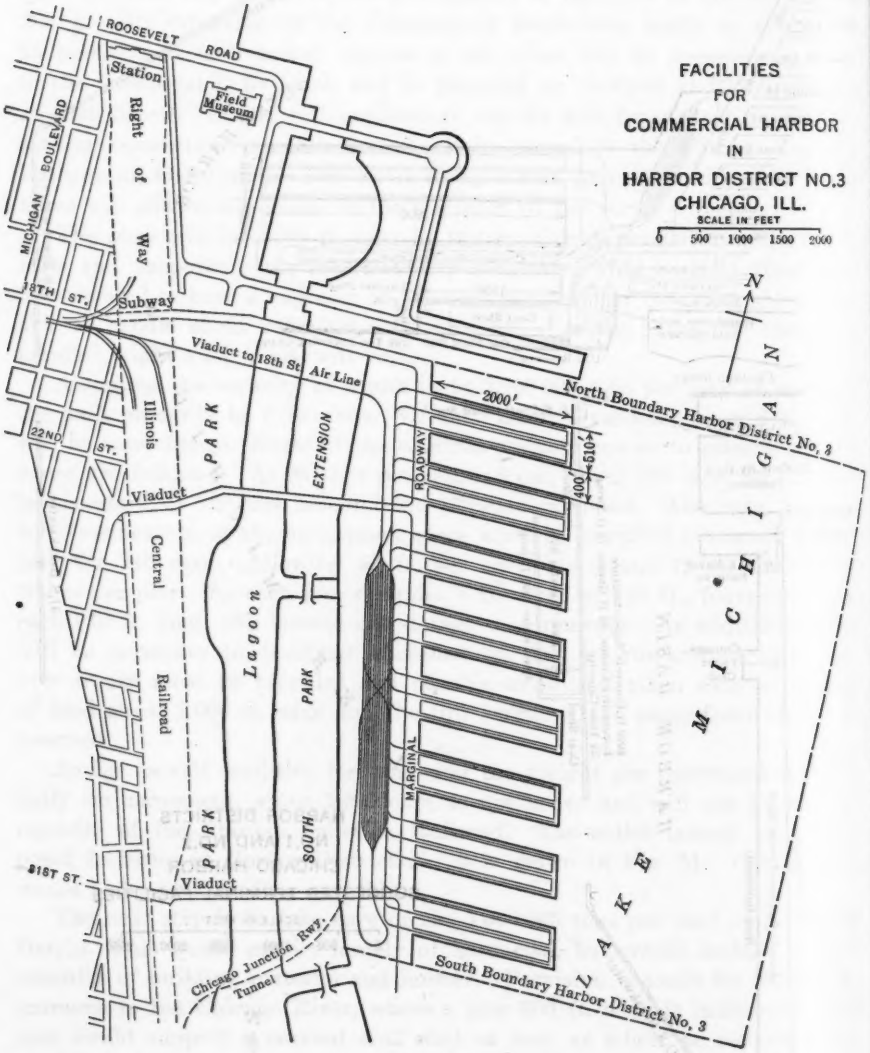


FIG. 51.

be used for storage of bulk materials as well as for loading and unloading, the transfer rate per year will be less than for the piers at Harbor District No. 3. Assuming an annual rate of 400 tons per lin. ft. per year, the capacity of each pier becomes 2 400 000 tons per year and ten piers will be necessary to handle the total of 23 500 000 tons.

Rail connections to both the Indiana Harbor Belt and the Elgin, Joliet and Eastern Railroads are possible at this site. As this harbor is intended for the interchange of commodities between lake and rail and lake and inland waterway, no highway facilities are necessary. The possibilities for provision of industrial harbor facilities are almost unlimited. With the Calumet River only partly utilized and Lake Calumet, Wolf Lake, and Hyde Lake entirely undeveloped, sites are available, which will answer requirements indefinitely. Following more complete occupation of sites along the Calumet River, the next step is the improvement of Lake Calumet. The Van Vlissingen plan, which was recently adopted by the City of Chicago and approved by the authorities of the State of Illinois and by the War Department, is an excellent layout for the purpose intended. As the project now approved by Congress for the improvement of the Calumet River, as far as the entrance to Lake

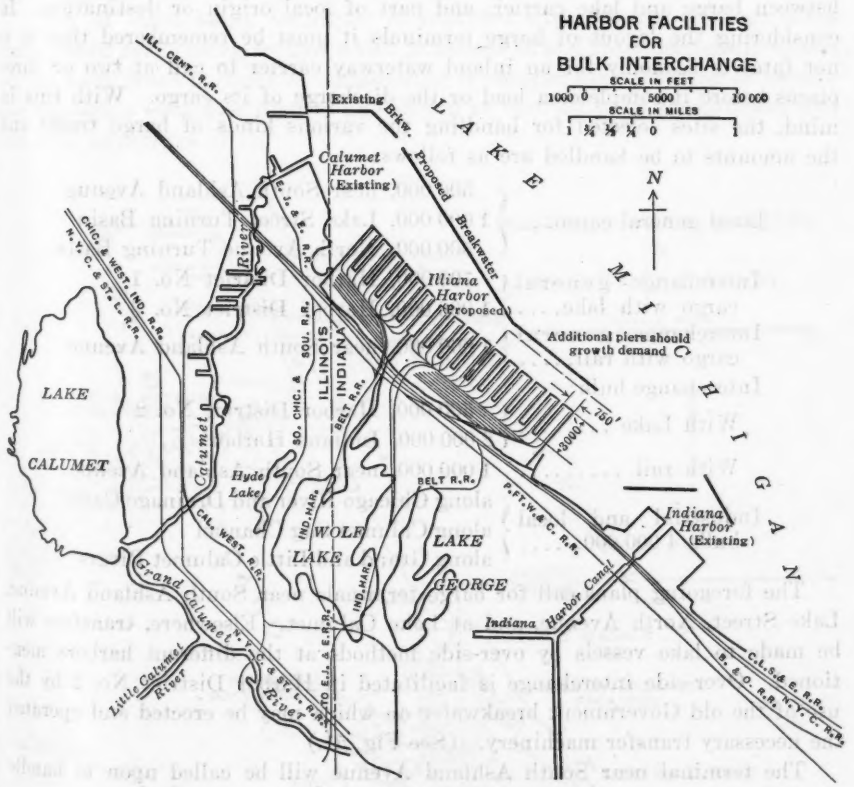


FIG. 52.

Calumet, provides for vessels drawing 21 ft., a usable channel for deep-draft navigation is assured. The proposed improvement for Lake Calumet will provide about 14 miles of water frontage. If that available on the river itself is added, about 80 000 ft., a total of 150 000 ft. is available. Assuming a usage of 150 tons per year per foot, which is low, there is a total capacity of

22 500 000 tons. By the addition of more slips at right angles to the Calumet River, and by the improvement of a few more miles of the river beyond Lake Calumet, it would be possible to double this capacity. The improvement of Wolf and Hyde Lakes along lines similar to those proposed for Lake Calumet would add capacity for perhaps 25 000 000 tons. It is, apparent, therefore, that the water-front and suitable land contiguous thereto is ample to take care of an enormous amount of this character of port facility.

Barge Traffic

It has been assumed that the barge traffic will total 12 000 000 tons per year and would be made up as follows:

General cargo	4 500 000 tons per year
Bulk freight	5 500 000 " " "
Industrial freight	2 000 000 " " "

Part of the general cargo is interchange between barge and rail, part between barge and lake carrier, and part of local origin or destination. In considering the layout of barge terminals it must be remembered that it is not fatal to economy for an inland waterway carrier to call at two or three places before it completes a load or the discharge of its cargo. With this in mind, the sites selected for handling the various kinds of barge traffic and the amounts to be handled are as follows:

Local general cargo...	500 000, near South Ashland Avenue 1 000 000, Lake Street Turning Basin 500 000, North Avenue Turning Basin
Interchange general cargo with lake....	500 000, Harbor District No. 1 1 000 000, Harbor District No. 3
Interchange general cargo with rail.....	1 000 000, near South Ashland Avenue
Interchange bulk:	
With Lake	500 000, Harbor District No. 2 2 000 000, Indiana Harbor
With rail	1 000 000, near South Ashland Avenue
Industrial and local bulk, 4 000 000.....	along Chicago River and Drainage Canal, along Calumet Sag Channel along Grand and Little Calumet Rivers

The foregoing plans call for barge terminals near South Ashland Avenue, Lake Street, North Avenue, and at Lake Calumet. Elsewhere, transfers will be made to lake vessels by over-side methods at the different harbors mentioned. Over-side interchange is facilitated in Harbor District No. 2 by the use of the old Government breakwater on which may be erected and operated the necessary transfer machinery. (See Fig. 51.)

The terminal near South Ashland Avenue will be called upon to handle the following:

Local general cargo	500 000 tons
Interchange with rail, general cargo	1 000 000 "
Interchange with rail, bulk	1 000 000 "
Total	2 500 000 tons

or, classified as regards method of treatment, 1 500 000 tons of general cargo and 1 000 000 tons of bulk freight.

The general cargo will be handled through a transit shed of the nature shown in Fig. 48. Assuming a transfer rate of 500 tons per ft. per year, 3 000 lin. ft. of transit shed is necessary. The bulk freight will be handled through storage yards. With a transfer rate of 400 tons per ft. per year, 2 500 ft. of frontage will be necessary. Rail connection is with the Chicago River and Indiana Railroad.

Provision must be made at Lake Street for handling a local general cargo of 1 000 000 tons. As this terminal is intended to serve only down-town shippers and consignees, no rail connections are necessary. For this terminal 2 000 ft. of transit shed will be necessary.

At North Avenue, provision must be made for 500 000 tons per year of local general cargo. This will require 1 000 ft. of transit shed.

Each of these barge terminals is provided with 200 ft. of single-story transit shed for housing freight which is carried to and from deep-draft vessels on the Lake front by lighters. Lightering is cheaper than trucking or switching through a congested district and should be resorted to by the shippers that can take advantage of it.

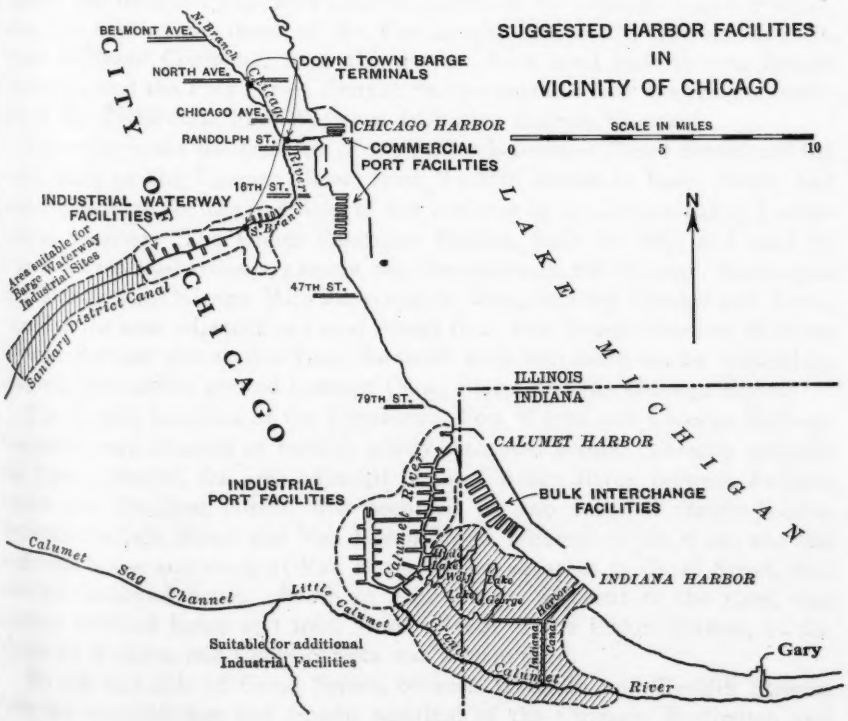


FIG. 53.

Résumé

These various layouts are assembled in one general diagram Fig. 53. Compare Fig. 53 with the plans made for an ideal port, as described previously and shown in Fig. 47. The commercial port facilities proposed for Chicago are nearly opposite the commercial center of the city. Provision has been made for interchange bulk and industrial freight in their proper places. Inland waterway terminals and connections are more than taken care of; and railroad arrangements meet the demands of rail and water interchange as well as local conditions.

The secret, if there is a secret, is that Chicago is blessed with physical characteristics which permit alteration of conditions to fit almost any given arrangement. Excavation is quite simple; filling in the foreshore of the Lake fairly easy; grades are light; and waterways and channels may be improved with comparative ease. What more can be desired?

THE MODERN FREIGHT TERMINAL OF THE PENNSYLVANIA RAILROAD SYSTEM IN CHICAGO, ILLINOIS

By William L. R. Haines,* M. Am. Soc. C. E.

This paper presents the underlying principles or influences that brought about the development of the present modern Pennsylvania Freight Terminal in Chicago, known as the Polk Street Freight Station. No attempt has been made to describe in detail the engineering features involved, but only to present a briefly historical and descriptive survey of the subject.

General Situation

For the sake of a clearer understanding of the situation, it seems well to explain that the Pennsylvania Lines West of Pittsburgh, although controlled by the Pennsylvania Railroad Company, were operated as a separate system, and that the City of Chicago was served by two divisions of this system; that is, the Pittsburgh, Fort Wayne and Chicago Railway Company and the Pittsburgh, Cincinnati, Chicago and St. Louis Railroad Company.

The tracks of the Pittsburgh, Fort Wayne and Chicago Railway Company reached the terminal passenger station, known as the Chicago Union Station, from the south, and those of the Pittsburgh, Cincinnati, Chicago and St. Louis Railroad Company, from the north. Each road had its own freight terminals, and the Polk Street Freight Station replaces only the freight facilities of the Pittsburgh, Fort Wayne and Chicago Railway Company.

For many years the facilities of the railroads between Canal Street and the south bank of the Chicago River, from Twelfth Street to Lake Street, had been inadequate for the handling of the business in an economical and satisfactory manner. The Union Passenger Station, built in 1881, and used by four great railroad systems, namely, the Pennsylvania, the Chicago, Burlington and Quincy, the Chicago, Milwaukee and St. Paul, and the Chicago and Alton, occupied the area adjacent to Canal Street from Van Buren Street to Madison Street. Serving this station from the south were four main tracks, occupying, roughly, the middle ground between Canal Street and the Chicago River.

The freight facilities of the Pittsburgh, Fort Wayne and Chicago Railway Company were situated at various widely separated points. Directly opposite the Union Station, the area adjacent to the Chicago River, between Jackson Street and Madison Street, was occupied by two inbound freight-houses. Between Jackson Street and Van Buren Street, adjacent to the river, was one outbound house and south of Van Buren Street, adjacent to Canal Street, was another outbound house. South of Polk Street, adjacent to the river, was another inbound house and team yard. North of the Union Station, at the corner of Madison and Canal Streets was a team yard.

On the east side of Canal Street, between Harrison and Twelfth Streets, were the engine-house and freight terminal of the Chicago, Burlington and

* Asst. Engr., Pennsylvania System, Pittsburgh, Pa.

Quincy Railroad Company. Between the main tracks leading to the Union Station and the river, the area between Polk Street and Van Buren Street was occupied by the freight yards and houses of the Chicago and Alton Railroad Company, with the exception of three plots occupied by Marshall Field and Company and the Chicago Edison Electric Company.

The plans for the new Union Station, now being constructed, called for the elimination of all the freight facilities of the Pittsburgh, Fort Wayne and Chicago Railway Company, with the exception of the small inbound house and team tracks, south of Polk Street, and for the serious curtailment of these and of the freight facilities of the Chicago, Burlington and Quincy Railroad and Chicago and Alton Railroad Companies.

Plate V shows the situation as it existed prior to the beginning of construction work on the new Union Station, with the outlines of the property required for the new Union Station shown in hachure. The location of the new freight facilities of the three railroads is superimposed.

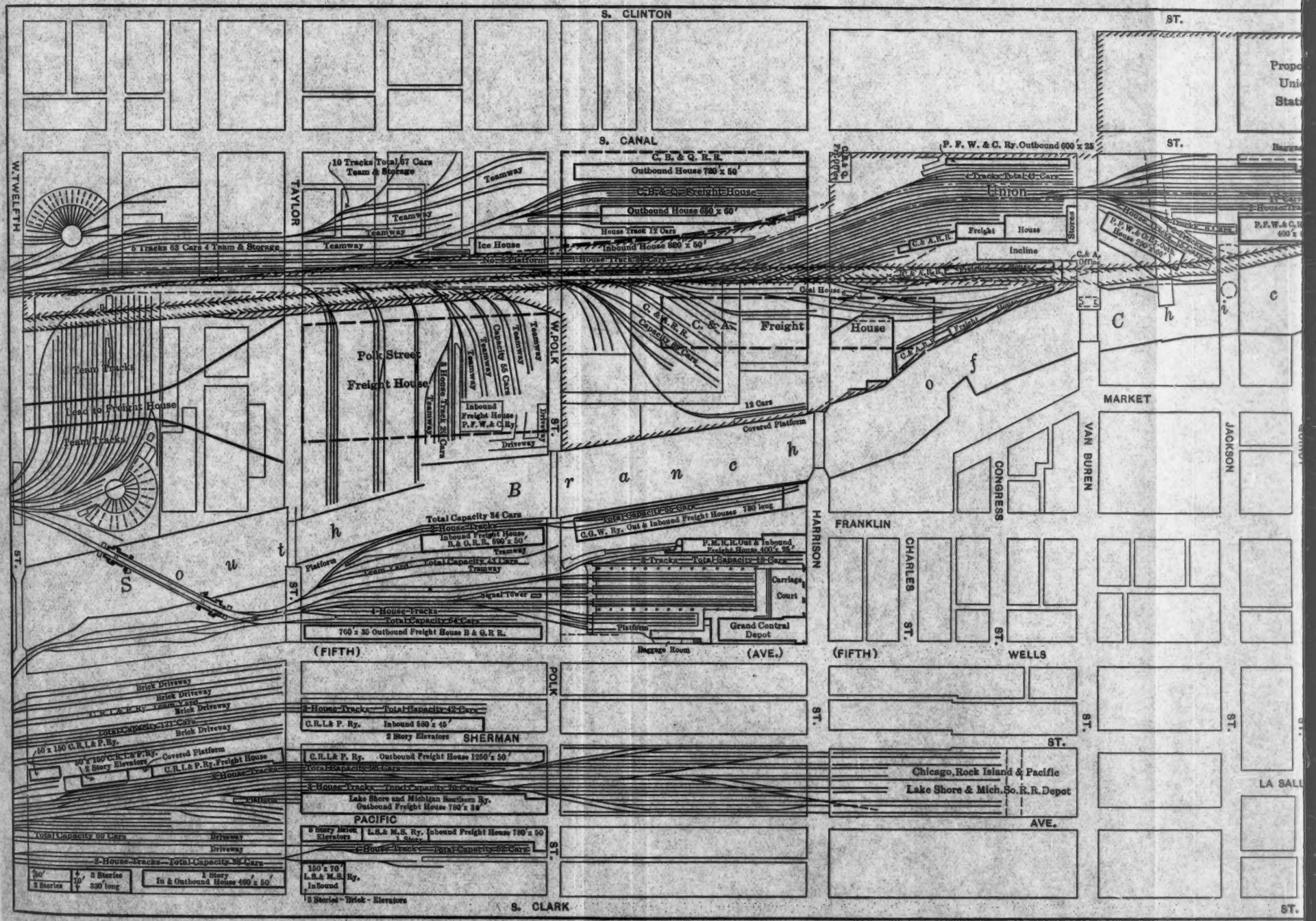
Proposed West Side Terminal

Faced with the problem of a rehabilitation of its principal freight facilities, the management of the Pennsylvania Lines, early in 1911, appointed a committee of engineering, operating, and traffic officers to develop plans for a new freight station. For some years prior the problem had been studied and a location for the freight station facilities had been selected and the property purchased. This site was bounded by Polk, Van Buren, Desplaines and Jefferson Streets, and required the construction of an elevated approach, extending diagonally from a point on the Pittsburgh, Fort Wayne and Chicago Railway, north of Eighteenth Street, to Fourteenth Street west of Jefferson Street, thence paralleling Jefferson Street to the freight station. When application was made to the Chicago City Council for the necessary franchises to carry out this development, the plan met with so much opposition (largely because of the elevated approach) from the City Council, the Chicago Plan Commission, and other civic bodies, that this location had to be abandoned.

The design of the proposed freight terminal was such a radical change from anything before attempted, that a brief description of it is believed to be warranted.

Plate VI shows the general plan, a cross-section, and a profile of the layout. Figs. 54, 55 and 56 are views, from different angles, of a plaster model of the proposed terminal. It will be noted that thought was given to the appearance of the structure, as well as to its utilitarian features, and that, from an architectural standpoint, it would have been a desirable addition to the buildings of the city.

The freight-house proper would have occupied the rectangle bounded by Van Buren, Jefferson, Harrison, and Desplaines Streets, with the house tracks on a level grade 21 ft. above the street level. The building was designed in three units running lengthwise of the rectangle, the units being separated by light shafts. Each unit contained four tracks and two platforms, and it was proposed to utilize two units for inbound and one for outbound freight.


S. CLINTON
S. CANAL
W. TWELFTH
TAYLOR
W. POLK
POLK
HARRISON
CHARLES
CONGRESS
VAN BUREN
JACKSON
MARKET
FRANKLIN
WELLS
LA SALLE
(FIFTH)
(AVE.)
SHERMAN
PACIFIC
S. CLARK
10 Tracks Total 67 Cars Team & Storage
5 Tracks 63 Cars 4 Team & Storage
Teamway
Ice House No. 2 Platform
C. B. & Q. R. R.
Outbound House 720' x 50'
C.B. & Q. Freight House
Outbound House 650' x 50'
House Track 12 Cars
Inbound House 620' x 50'
1 House Track 60 Cars
C. & A. R. R.
C. & A. Freight House
Capacity 55 Cars
Polk Street Freight House
Team Tracks
Lead to Freight House
3 House Track 36 Cars
Inbound Freight House P. F. W. & C. Ry.
Driveway
12 Cars
Covered Platform
Total Capacity 34 Cars
2 House Tracks
Inbound Freight House B. & O. R. R. 690' x 50'
Tramway
Platform
Team Yard
Total Capacity 41 Cars
Signal Tower
4 House Tracks
Total Capacity 84 Cars
760' x 35' Outbound Freight House B. & O. R. R.
Total Capacity 80 Cars
Total Capacity 171 Cars
C. R. I. & P. Ry.
Brick Driveway
50' x 150' C. R. I. & P. Ry. 3 Story Elevators
Covered Platform
C. R. I. & P. Ry. Freight House
3 House Tracks
2 House Tracks—Total Capacity 42 Cars
C. R. I. & P. Ry. Inbound 580' x 45'
2 Story Elevators
C. R. I. & P. Ry. Outbound Freight House 1250' x 50'
Total Capacity 36 Cars
3 House Tracks—Total Capacity 84 Cars
Lake Shore and Michigan Southern Ry. Outbound Freight House 780' x 30'
5 Story Brick Elevators
L. S. & M. S. Ry. Inbound Freight House 780' x 50'
1 Story
4 House Tracks—Total Capacity 52 Cars
150' x 70' L. S. & M. S. Ry. Inbound
3 Stories—Brick—Elevators
2 House Tracks—Total Capacity 56 Cars
50' 3 Stories
3 Stories 320' long
1 Story In & Outbound House 400' x 50'
P. F. W. & C. Ry. Outbound 600' x 25'
6 Tracks Total 6 Cars
Union
Freight House
Incline
C. & A. Office
Coal House
C. & A. R. R. Freight House
P. F. W. & C. Ry. House 290' x 40'
Grand Central Depot
Baggage Room
Total Capacity 84 Cars Inbound Freight House B. & O. R. R. 690' x 50'
Total Capacity 84 Cars C. G. W. Ry. Out & Inbound Freight Houses 780' long
F. M. R. R. Out & Inbound Freight House 400' x 25'
3 Tracks—Total Capacity 12 Cars
Carriage Court
Chicago, Rock Island & Pacific
Lake Shore & Mich. So. R. R. Depot
AVE.
Branch
South
ST.

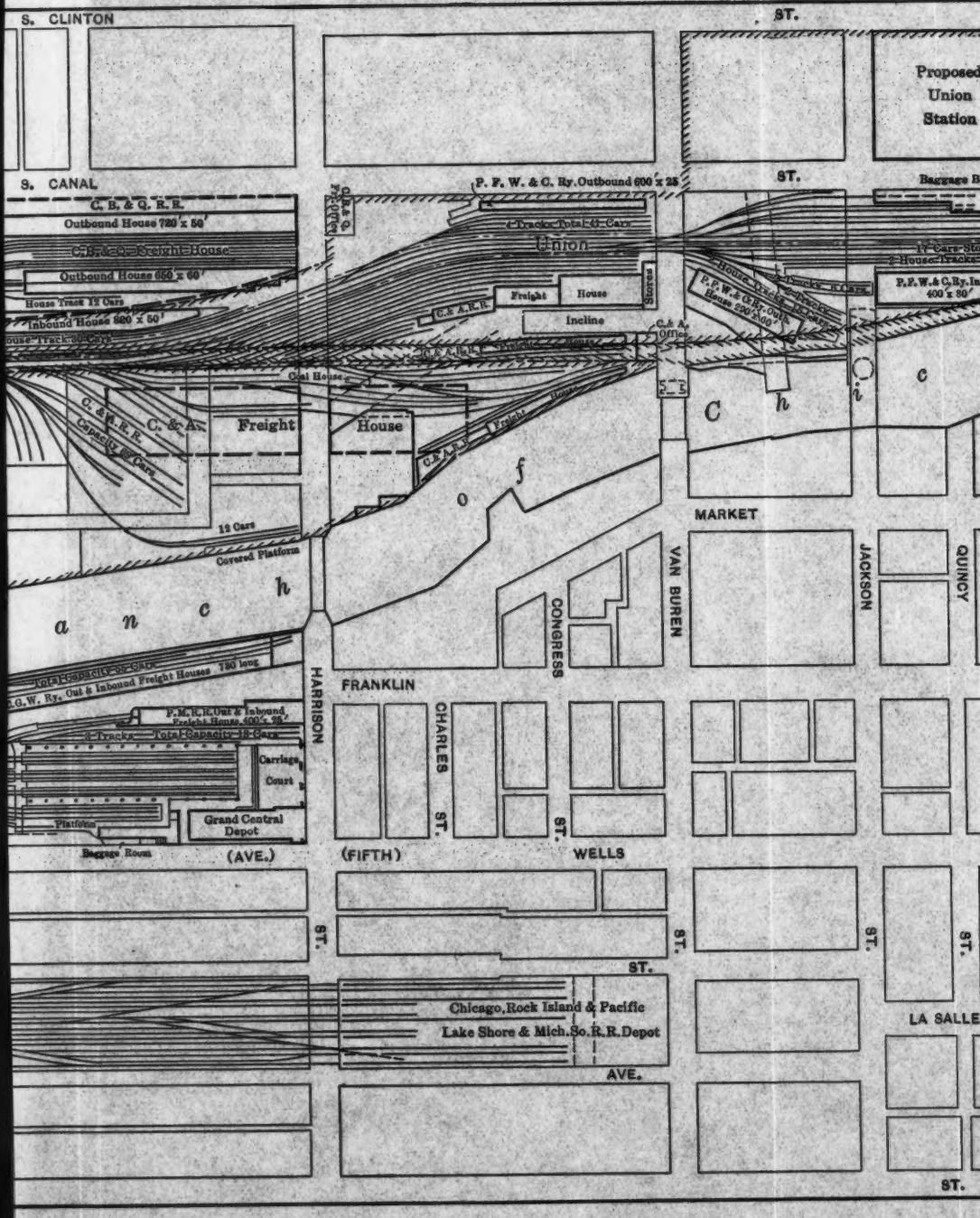

S. CLINTON
ST.
Proposed Union Station
S. CANAL
C. B. & Q. R. R.
Outbound House 720' x 50'
C. B. & Q. Inbound House
Outbound House 650' x 60'
House Track 12 Cars
Inbound House 600' x 50'
House Track 30 Cars
P. F. W. & C. Ry. Outbound 600' x 25'
Tracks Total 45 Cars
Union
Freight
House
Incline
C. & A. Office
Coal House
C. & A. R. R.
Capacity 60 Cars
12 Cars
Covered Platform
Canal
Office
MARKET
VAN BUREN
JACKSON
QUINCY
CONGRESS
HARRISON
FRANKLIN
CHARLES ST.
WELLS ST.
Total Capacity 30 Cars
C. G. W. Ry. Out & Inbound Freight Houses 730 long
P. M. R. R. Out & Inbound Freight House 400' x 25'
3 Tracks Total Capacity 12 Cars
Carriage Court
Platform
Grand Central Depot
Baggage Room
(AVE.)
(FIFTH)
ST.
Chicago, Rock Island & Pacific
Lake Shore & Mich. So. R. R. Depot
AVE.
LA SALLE
ST.

PLATE V.
PAPERS, AM. SOC. C. E.
SEPTEMBER, 1923.
HAINES ON
PENNSYLVANIA FREIGHT TERMINAL,
CHICAGO, ILL.

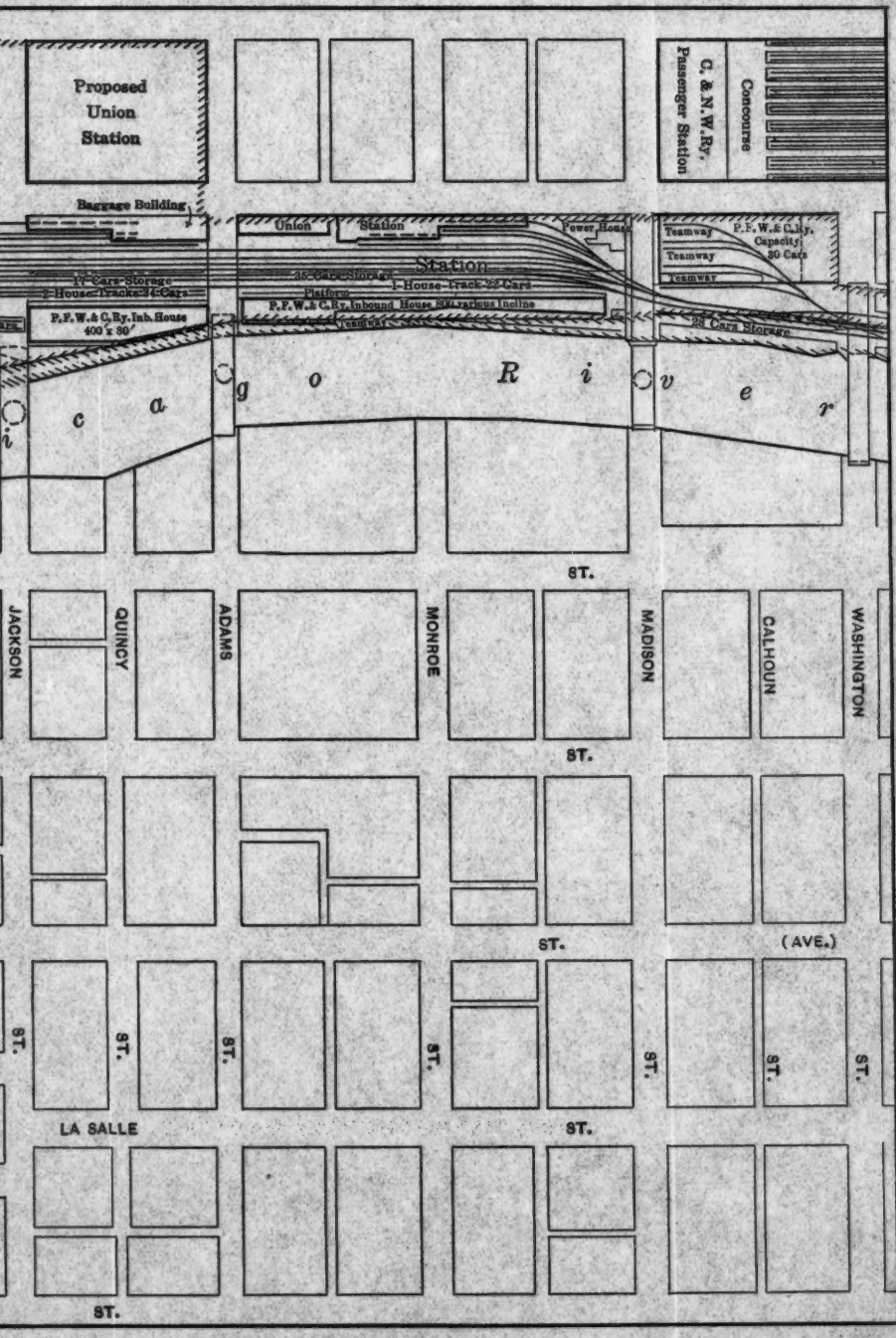
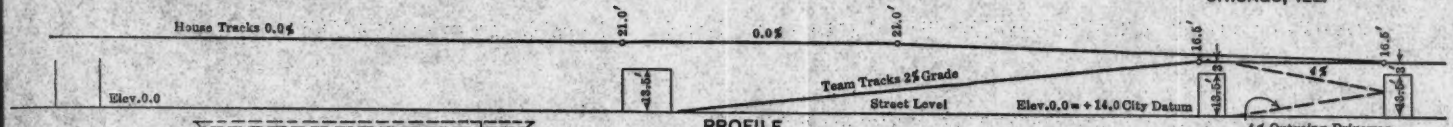
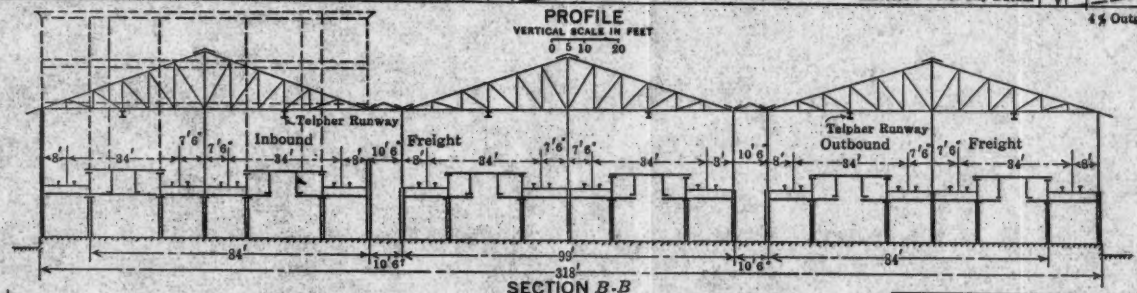
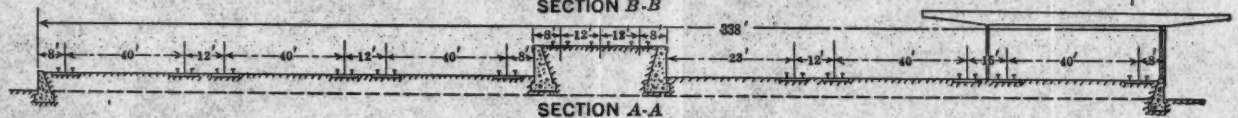


PLATE VI.
PAPERS, AM. SOC. C. E.
SEPTEMBER, 1923.
HAINES ON
PENNSYLVANIA FREIGHT TERMINAL,
CHICAGO, ILL.

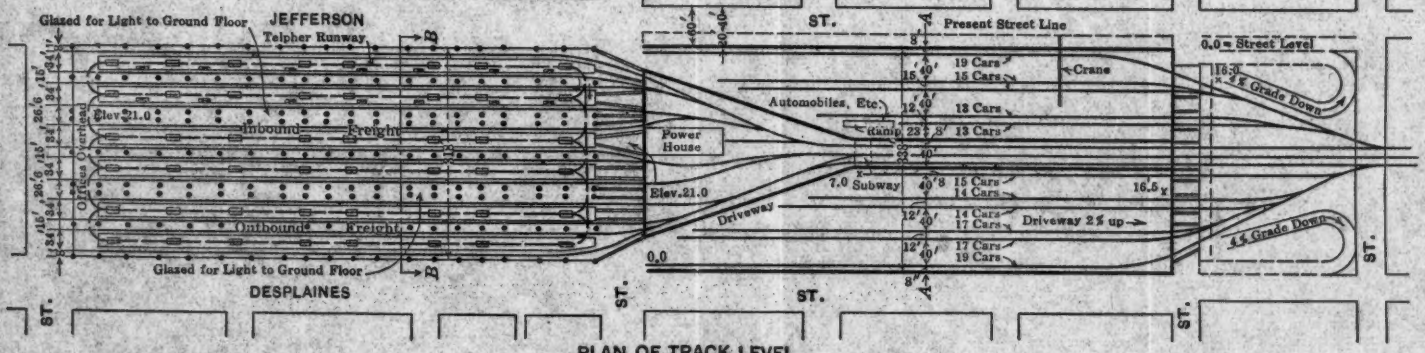




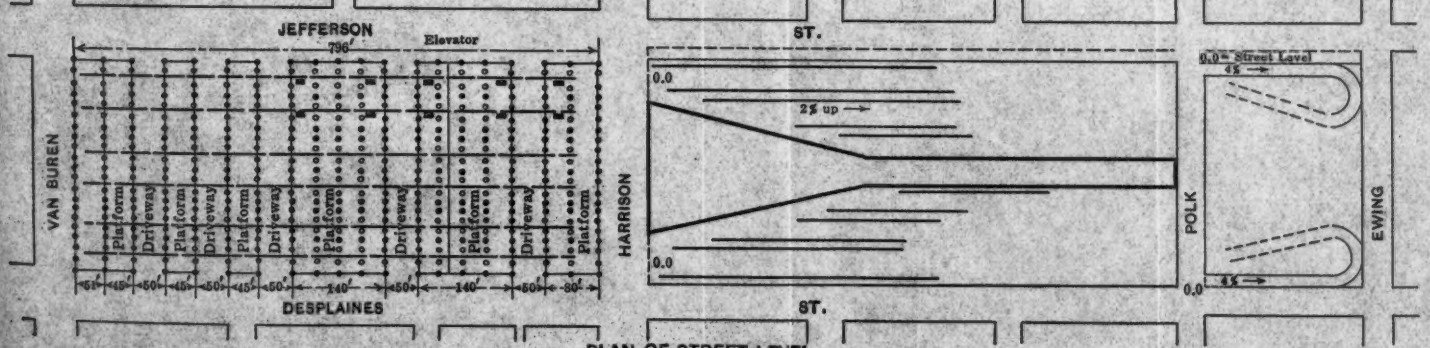
SECTION *B-B*



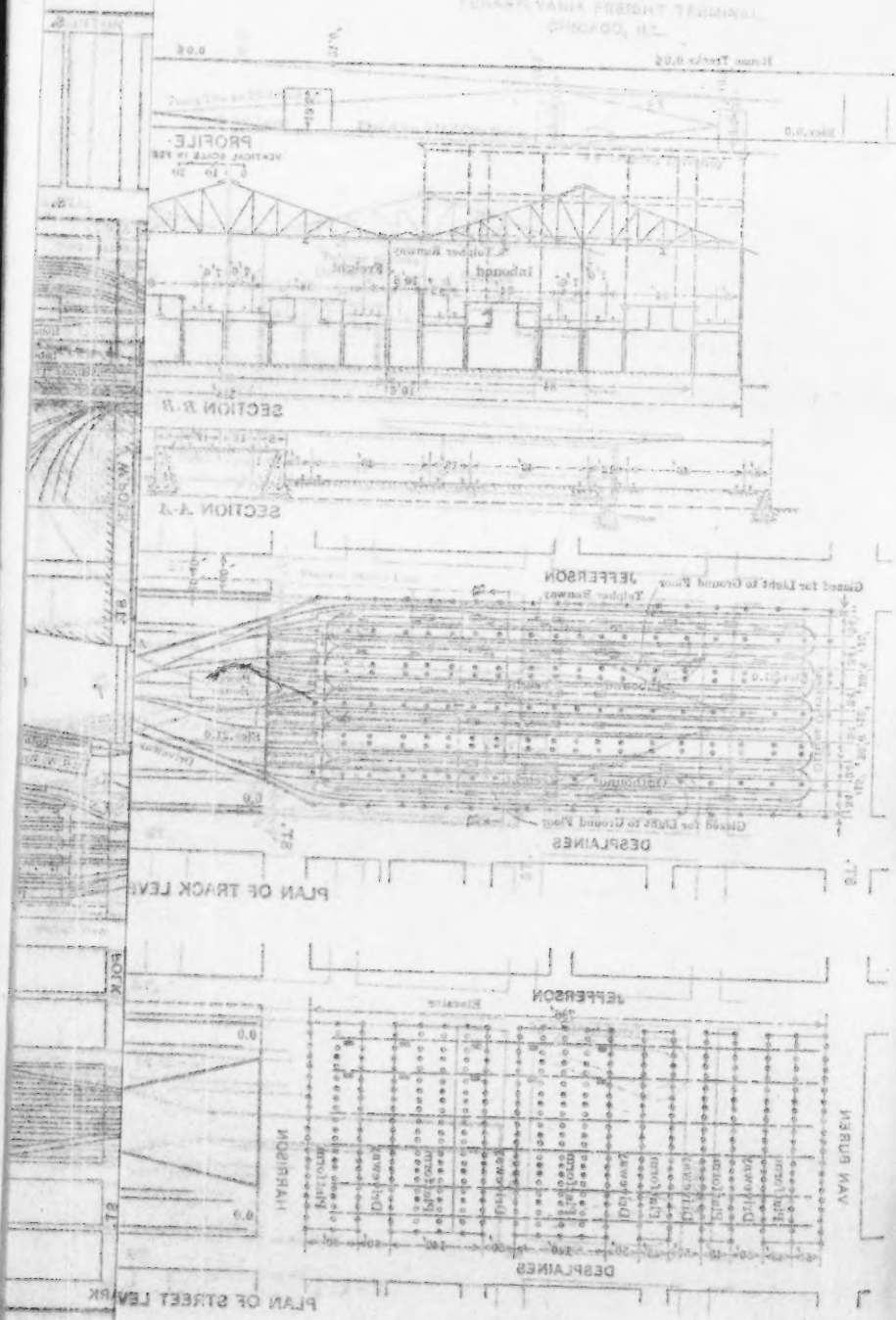
SECTION *A-A*



PLAN OF TRACK LEVEL



PLAN OF STREET LEVEL


PROFILE
SECTION B-B
SECTION A-A
JEFFERSON
DESPLAINES
PLAN OF TRACK LEVEL
HARRISON
VAN BUREN
PLAN OF STREET LEVEL

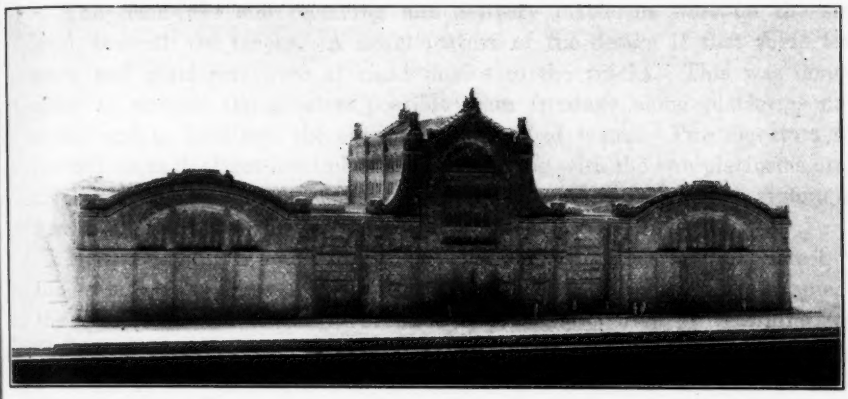


FIG. 54.—FRONT VIEW OF PLASTER MODEL OF PROPOSED FREIGHT TERMINAL OF THE PENNSYLVANIA RAILROAD IN CHICAGO, ILL.

FIG. 55.—SIDE VIEW OF PLASTER MODEL OF PROPOSED FREIGHT TERMINAL OF THE PENNSYLVANIA RAILROAD IN CHICAGO, ILL.

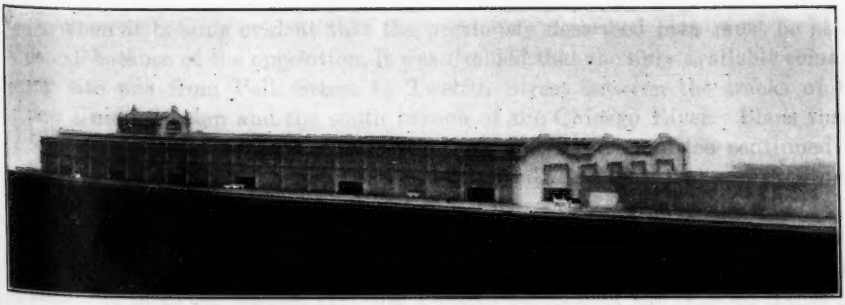


FIG. 56.—SIDE VIEW OF PLASTER MODEL OF PROPOSED FREIGHT TERMINAL OF THE PENNSYLVANIA RAILROAD IN CHICAGO, ILL.

The teamways and receiving and delivery platforms were on the street level, beneath the tracks. A novel feature of the design is that these teamways and platforms were at right angles to the tracks. This was done in order to provide the greatest possible team frontage along platforms under cover, and to facilitate the entrance and exit of teams. Two elevators were located on each street-level platform, connecting with the two platforms on the track level in the inbound house. A complete overhead telpherage system connected all the platforms on the track level.

In the rectangle, south of Harrison Street, extending to Polk Street, was the team yard. The center of the rectangle, longitudinally, was occupied by the three approach tracks to the freight-house, supported by retaining walls. On either side were team tracks and driveways on a 2% grade, descending from Polk Street to Harrison Street. The entrance to the driveways was at Harrison Street and the exit at Polk Street by means of two curved ramps on a descending 4% grade.

The intensive development of the ground area available is indicated by the following tabulation:

Total area of ground		630 000 sq. ft.
Floor area, street level	157 400 sq. ft.	
Platform area, track level	107 400 " "	
Driveway area, house	245 000 " "	
Team-track area, etc.	373 300 " "	
Total		883 100 sq. ft.

Length of house units	796 ft.
Total length of house	2 388 "
Total length of team frontage	3 498 "
Ratio: Floor area to team frontage	45:1
Capacity of house track	216 cars
Capacity of team tracks	171 cars

Polk Street Location

When it became evident that the previously described plan must be abandoned, because of the opposition, it was decided that the only available remaining site was from Polk Street to Twelfth Street between the tracks of the new Union Station and the south branch of the Chicago River. Plans therefore were prepared to cover this situation, and the Committee continued its investigations, finally recommending substantially the plan that was eventually followed.

Fig. 57 shows the general layout adopted. The team-track development has been modified somewhat and is at present in an incomplete condition, and must remain so until the viaduct carrying Twelfth Street over the railroad tracks has been reconstructed. Reference to Plate V will show the location of the freight-house site and the facilities existing thereon prior to its construction.

PROPOSED FREIGHT TERMINAL
AND
YARD FACILITIES
12TH STREET
TAYLOR STREET
POLK STREET
Proposed Dividing Line with B. & O.
8°
Dock Line
River
Driveway
Team Tracks 198 Cars
Team Tracks 177 Cars
Driveway
Outbound House 180 Cars
Inbound House 187 Cars
Ordinance Channel Line
Chicago
of
South
Branch
Reserved Strip for C. A. & C. R. R.
Joint Tracks
Chicago Union Station Tracks
C. & A. Freight Yard
PROFILE
SCALE IN FEET
HORIZONTAL
VERTICAL
Grade varies from 0.97% to 2.11% on Team Tracks
Approach to Freight House
Driveway Level
Top of Rail Present Main Tracks
House Tracks

FIG. 57.

Plan of Station

Because of the high cost of the limited area available, and the impossibility of obtaining additional ground, it was necessary to develop this area to its utmost capacity, which could only be done by building a multiple-story freight station.

All the streets crossing the railroad from Twelfth Street, north, were carried on viaducts over the tracks, so that it was convenient and less costly for the teamways and delivery platforms to be on the upper, or street level, with the tracks and loading platforms on the lower level. The studies already made had largely determined the relative amount of space to be devoted to various uses, so that the question became one of fitting these facilities to the site. The success with which this was done may be judged by reference to Figs. 58 and 59, which show, respectively, the track level and street level of the building.

In addition to the track and street level floors, which are used exclusively for freight-house purposes, the building has three floors designed for use as a warehouse. A typical plan of these three warehouse floors is shown on Fig. 60. Figs. 61 and 62 show longitudinal and cross-sections through the house.

On the track level are nineteen tracks, each with a platform adjacent. These platforms vary in width from 5 ft. 6 in. to 27 ft. 10 in. On the street level, the house is divided by a central driveway into two units, one 171 ft. wide for inbound, and the other 100 ft. wide for outbound, freight. This central driveway is 76 ft. wide, with a row of columns down the center, so that each house is served by an independent driveway 38 ft. wide. In addition, there is another driveway of the same width along the outer side of each house. All these driveways extend through from Polk Street to Taylor Street.

The width of the inbound house was governed partly by the necessity for large storage space on the street level, but a major consideration in determining the widths of both houses was the spacing of tracks and platforms and the location of elevators. The outbound house required comparatively little space for storage on the street level, but on the track level it required as much space as the inbound house. Somewhat more space on the street level was given to the outbound house than was actually required, but this was unavoidable because of the outbound track requirements.

Reference to cross-section, Fig. 62, will show how this problem was solved. It will be noted that there is a platform between each pair of tracks, except the adjacent tracks of the inbound and outbound groups at the center of the house. Most of these platforms are narrow, being intended primarily for trucking through cars, without spotting, but under the inbound house are three, and under the outbound house two, wide platforms with elevators.

Elevator Arrangement

All freight is received and delivered on the street level and is handled between this and the track level and the various warehouse floors by electric elevators. Thirty-two of these elevators have been installed, and provision has been made for the addition of eighteen more as the growth of business

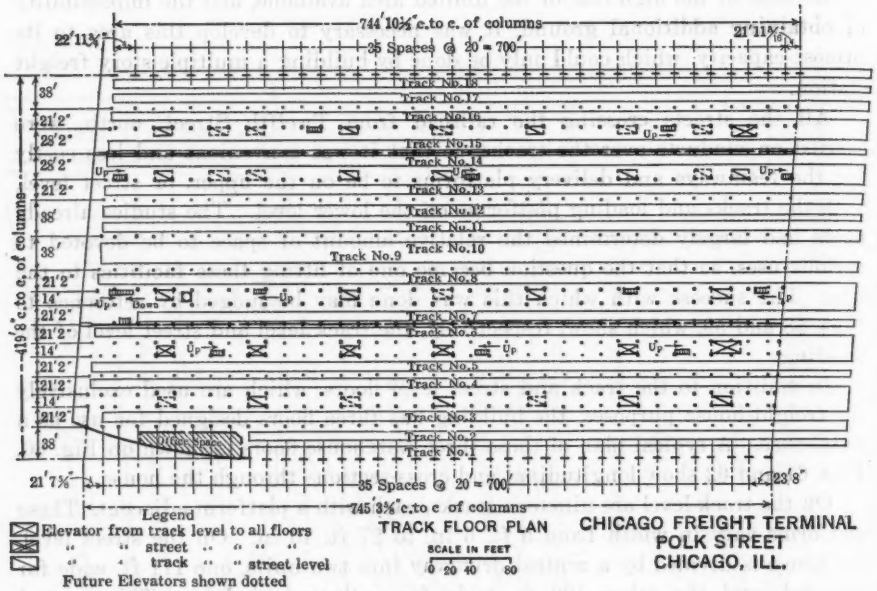

744′10½″ c.to c. of columns
22′11½″
35 Spaces @ 20′ = 700′
21′11½″
Track No.18
Track No.17
Track No.16
Track No.15
Track No.14
Track No.13
Track No.12
Track No.11
Track No.10
Track No.9
Track No.8
Track No.7
Track No.6
Track No.5
Track No.4
Track No.3
Track No.2
Track No.1
419′8″ c.to c. of columns
21′7½″
35 Spaces @ 20′ = 700′
23′8″
745′3½″ c.to c of columns
Legend
Elevator from track level to all floors
" " street " " " "
" " track " " street level
Future Elevators shown dotted
TRACK FLOOR PLAN
SCALE IN FEET
0 20 40 80
CHICAGO FREIGHT TERMINAL
POLK STREET
CHICAGO, ILL.

FIG. 58.

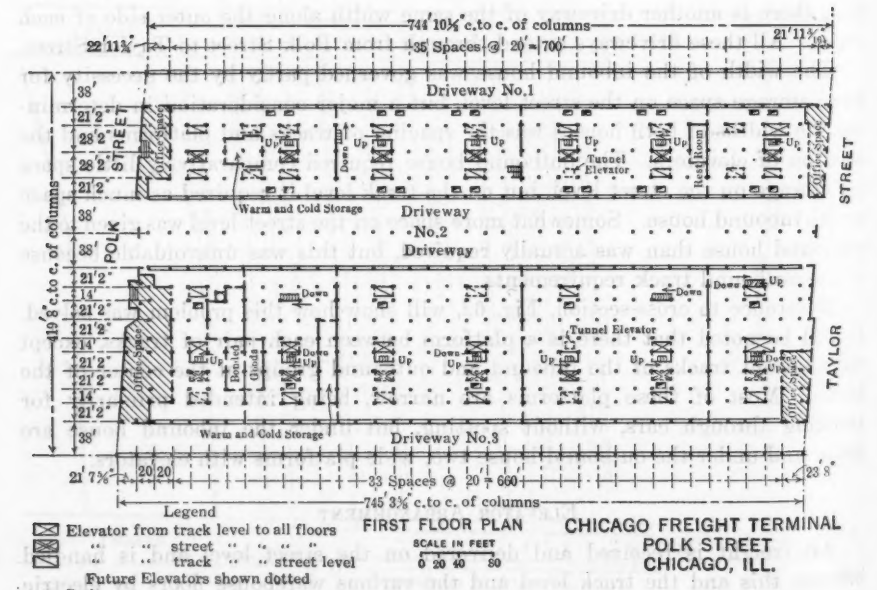

744′10½″ c.to c. of columns
22′11½″
35 Spaces @ 20′ = 700′
21′11½″
Driveway No.1
STREET
Warm and Cold Storage
Driveway
No.2
Driveway
POLK
Tunnel Elevator
TAYLOR
Warm and Cold Storage
Driveway No.3
419′8″ c.to c. of columns
21′7½″
20 20
33 Spaces @ 20′ = 660′
23′8″
745′3½″ c.to c. of columns
Legend
Elevator from track level to all floors
" " street " " " "
" " track " " street level
Future Elevators shown dotted
Scales
FIRST FLOOR PLAN
SCALE IN FEET
0 20 40 80
CHICAGO FREIGHT TERMINAL
POLK STREET
CHICAGO, ILL.

FIG. 59.

demands. Consideration was given to the use of escalators and chutes, but after a thorough investigation, it was decided that their use would not be warranted here.

One of the thirty-two elevators is a passenger elevator, which operates from the street floor to the seventh floor in the tower. This tower rises 190 ft. above the level of the street and 130 ft. above the roof of the main building. It is divided into eight stories, seven of which are octagonal in shape, with alternate faces 28 ft. and 11 ft. long. The first three floors are used for the filing of records and for similar purposes. Between the fourth and sixth floors is a 50 000-gal., steel, water tank for fire protection. On the sixth floor is a large clock with four dials, each 16 ft. in diameter. Between the seventh and eighth floors is an inset balcony and, above this, the tower rises 30 ft. square to a pyramidal roof.

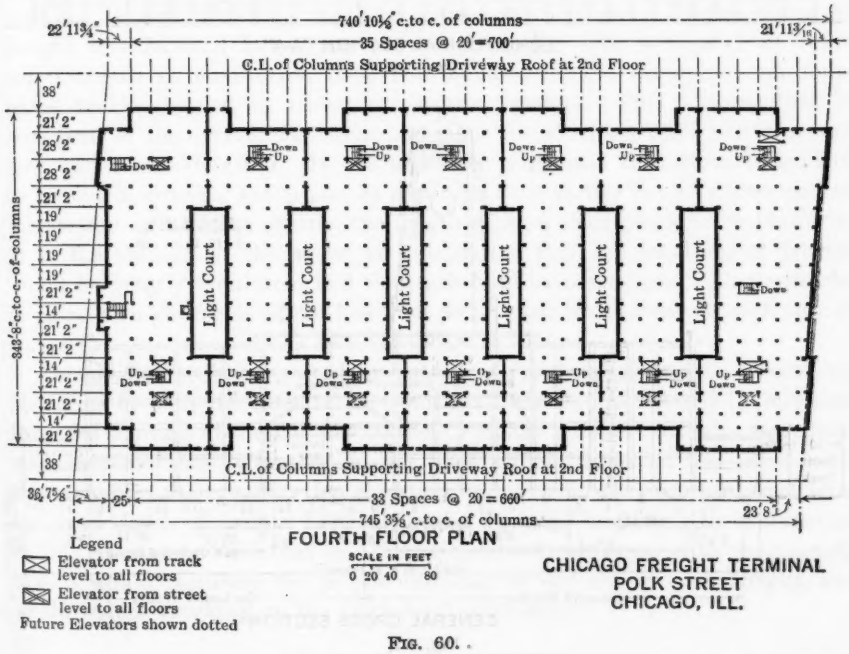

740' 10½" c. to c. of columns
35 Spaces @ 20' = 700'
C.L. of Columns Supporting Driveway Roof at 2nd Floor
Light Court
343' 8" c-to-c-of-columns
745' 3⅝" c. to c. of columns
33 Spaces @ 20' = 660'
Legend
Elevator from track level to all floors
Elevator from street level to all floors
Future Elevators shown dotted
FOURTH FLOOR PLAN
SCALE IN FEET
0 20 40 80
CHICAGO FREIGHT TERMINAL
POLK STREET
CHICAGO, ILL.

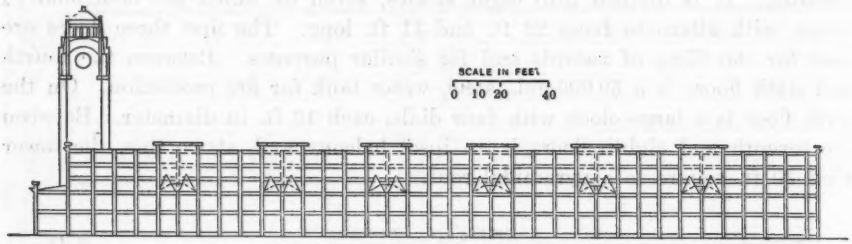
FIG. 60.

In the inbound house there are eight elevators (ultimately to be sixteen) of 3-ton capacity, with 6 by 17-ft. platforms, running between the track level and the first floor; seven elevators of 5-ton capacity, with 9 by 17-ft. platforms, running from the first floor to the three warehouse floors; and one of 10-ton capacity with a 10 by 24 ft.-platform for handling automobiles from the track level to the three warehouse floors.

In the inbound house there are eight elevators (ultimately to be twelve) of 5-ton capacity, with 9 by 17-ft. platforms, from the track level to the first floor; one elevator of the same size from the first floor to the three warehouse floors; five of the same size from the track floor to the three warehouse floors; and one

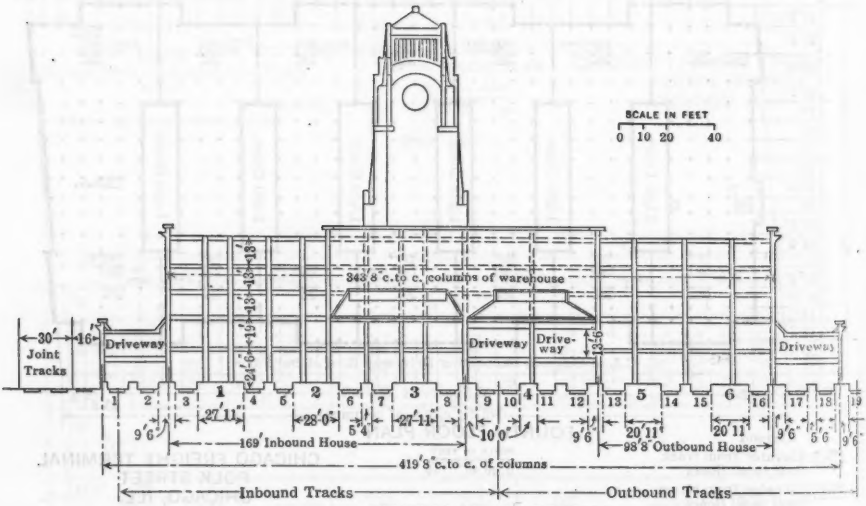
10-ton automobile elevator, with a 10 by 24-ft. platform, from the track level to the three warehouse floors.

Direct communication by elevator between the warehouse floors and the track level was avoided, with the exception of the automobile elevators, to prevent a possibility of goods in the warehouse being shipped out without being properly billed and checked.



LONGITUDINAL SECTION "A-A"

FIG. 61.



GENERAL CROSS SECTION

FIG. 62.

POWER PLANT

At the north end of the building is a large sub-basement extending to about 15 ft. below river level. In this sub-basement are located the pumps for the fire protection system, and the heating plant, which includes three 150-h.p. boilers. All electric power for light, operating elevators, pumps, and other purposes, is purchased from commercial circuits.

METHODS OF HANDLING FREIGHT

In the design of this freight-house, it was a fundamental consideration that it would be operated as a less-than-carload freight-house for inbound and

outbound freight only, and that no "transfer" business should be done there, the intention being to build a modern transfer station at an outlying point. With this in mind, wide platforms, which are principally useful for the piling and sorting of freight, appeared to be unnecessary. An ample number of elevators were provided, and it was intended that inbound freight should be taken from the car to the nearest elevators, the trucking being done through intervening cars, where necessary, the narrow platforms avoiding the necessity for spotting car doors opposite one another. Outbound freight, received on the street level, and there sorted, would move on that floor to an elevator nearest the car to which the freight was destined, thus avoiding the necessity for trucking longitudinally of the freight-house on the track level.

The exigencies of business, however, have prevented the construction of a separate transfer station and have made it necessary to conduct transfer operations, as well as the inbound and outbound freight business, in this station. Freight-handling methods have also changed. Where formerly freight was handled largely on two-wheel trucks, with a number of four-wheel trucks as auxiliaries, it is now handled almost exclusively on four-wheel trucks, hauled in trains by electric tractors. This has resulted in criticisms of the narrow platforms, and plans for widening these platforms are now under consideration. It has also been suggested that movable bridges be provided, crossing the tracks at platform level at the Taylor Street end of the station, in order to shorten the length of haul from platform to platform. It is the opinion of the agent at this station that the handling of freight would be greatly facilitated had the track level been arranged with the tracks in pairs with platforms of not less than 30 ft. clear width between each pair of tracks.

In addition to being served by entrances from the street, the street-level platforms in both the inbound and outbound houses are reached by elevators from the subways of the Illinois Tunnel Company. Some criticisms have been made because these elevators do not open on platforms on the track level, thus avoiding the necessity for elevating or lowering, between the street level and track level, of freight handled by the Tunnel Company. In explanation of this, it may be said that the arrangement provided was with the thought that it would facilitate the proper checking in and out of such freight, and would reduce trucking on the track-level platforms.

Details of Construction

The building is of steel frame, fire-proof construction, the steelwork being encased in concrete, with brick curtain walls. The foundation consists of reinforced concrete piers supported by wooden piles, about 18 000 piles, driven to a depth of 40 to 50 ft., being used. The floors and roof slabs are of reinforced concrete.

There is a complete fire protection system on all floors, with more than 15 000 automatic sprinklers supplied by a 50 000-gal. steel tank and by two motor-driven fire-pumps fed by 14 in. suction lines, from the Chicago River. The warehouse is divided into seven independent sections by brick fire-walls.

Fire-walls have also been provided on the track level, dividing this space into three longitudinal sections, and on the street level dividing both the inbound and outbound houses into four sections each.

Ample space has been provided for cold and warm storage and for bonded goods. A complete system of inter-communicating telephones, pneumatic tubes for handling freight bills, vacuum-cleaning system, toilet, rest, and lunch rooms, and other modern accessories, have been provided.

Some statistical data are given in the following tabulation:

Size of building	750 by 420 ft.
or	315 000 sq. ft.
Floor space	850 000 sq. ft.
Floor area (street level)	199 700 sq. ft.
Team frontage	2 800 lin. ft.
Ratio: floor area to team frontage	71 : 1
Capacity of house tracks	375 cars
Driveway area (house)	114 000 sq. ft.
Team-track area	543 900 sq. ft.
Team-track capacity	357 cars

Architectural Appearance

Architecturally, the building is of imposing appearance. Its massive outlines dominate the entire district. The design is marked by simplicity of outline, with bold, although subdued, contrast of color, and is accentuated by its breadth of light and depth of shadow. The covered driveways on either side of the building, supported by arches opening to the track level, form a broad, unbroken base, above which rise the walls of the warehouse, their surfaces broken by offsets following the lines of the piers. Buttresses, curved at the base and tapering to a straight line at the top, and massive arches, introduced at salient points, prevent monotony and assist in procuring effective masses of light and shadow. The predominating note as viewed from either side is the tower, which appears to bind the Polk Street façade into an harmonious whole. The long stretch of roof is broken by the deck-houses, necessary for the elevator shafts, these deck-houses being treated as integral parts of the structural design, and blended with the main structure, thus avoiding the ugly roof lines so often seen. Figs. 63 and 64 are views of the building.

The materials used in obtaining the harmonious structural and color effects were an inexpensive grade of rough textured commercial brick of a dark reddish tone, and trimmings of glazed terra cotta, the original green of which has darkened and colored so as to blend with the darker shades of the brick. The tower is roofed with green tile.

It should be particularly emphasized that there has been no waste of space nor prodigal use of materials, and no sacrifice of economy nor of utilitarian purpose for the sake of artistic effect. The building is an object lesson—a contradiction of the too often held theory that a structure of purely utilitarian purpose is beyond the possibilities of beautiful architectural expression.

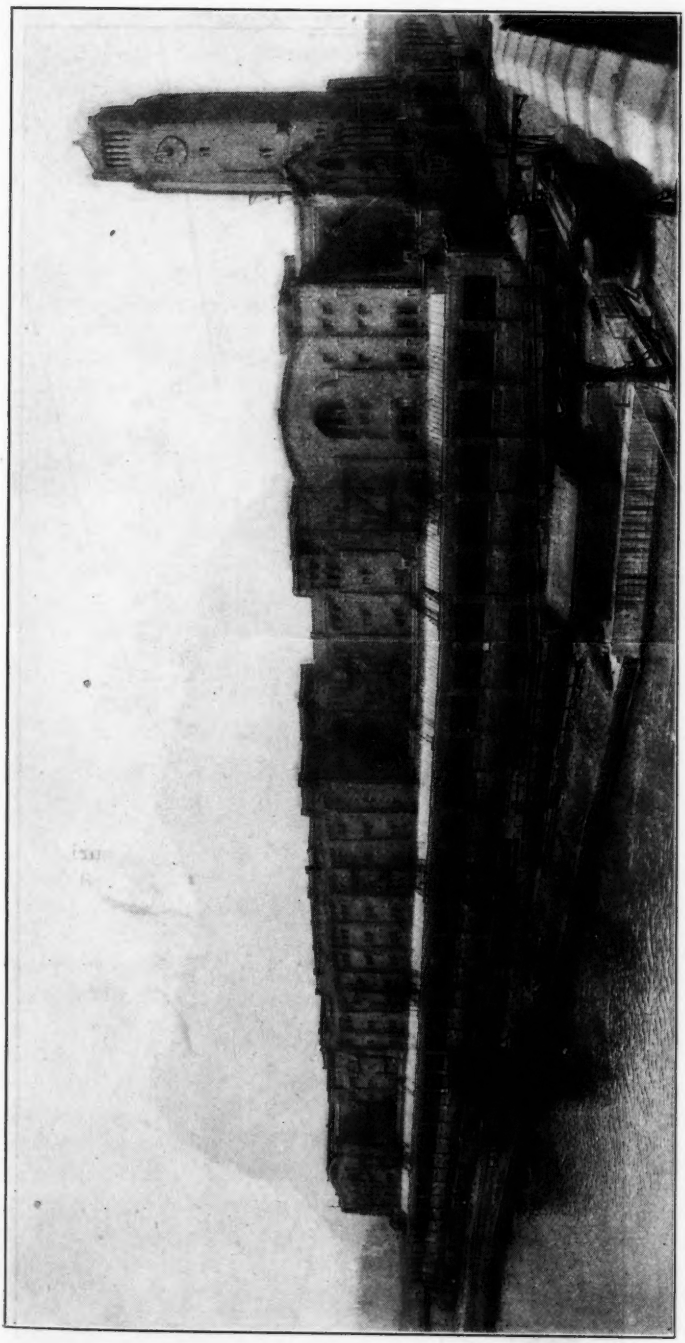
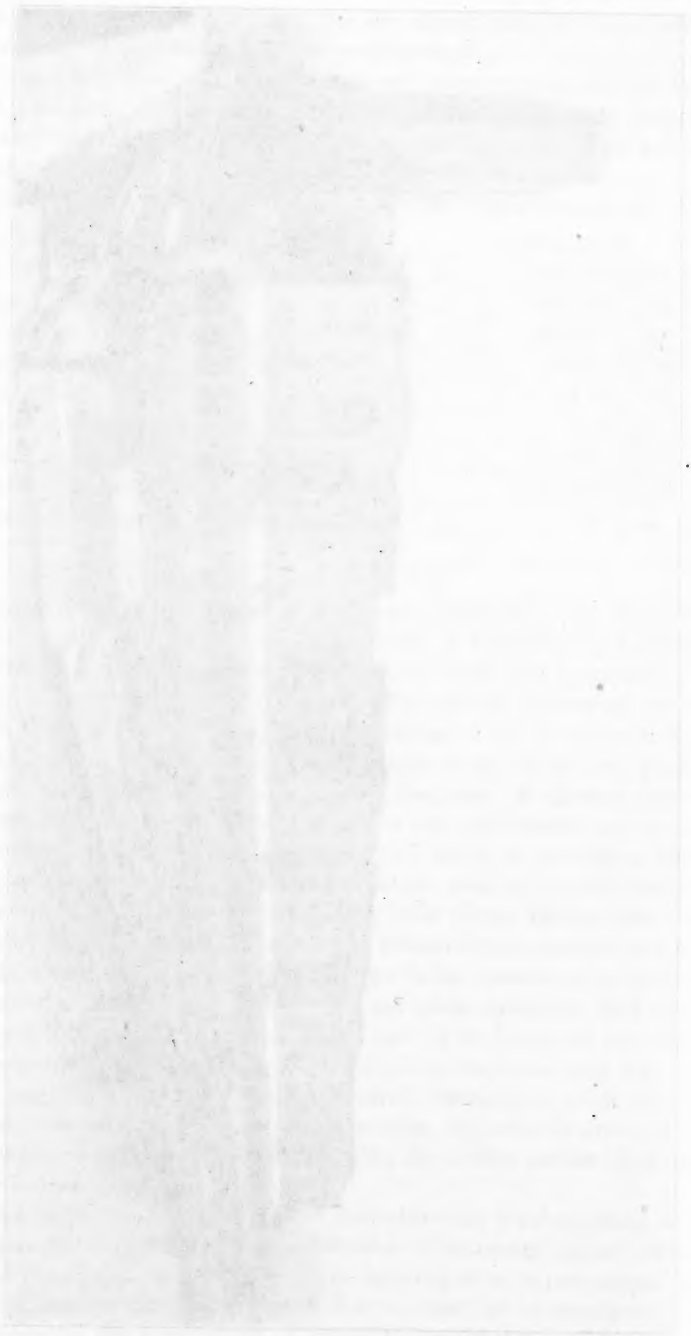


FIG. 63.—VIEW OF COMPLETED FREIGHT TERMINAL OF THE PENNSYLVANIA RAILROAD IN CHICAGO, ILL.



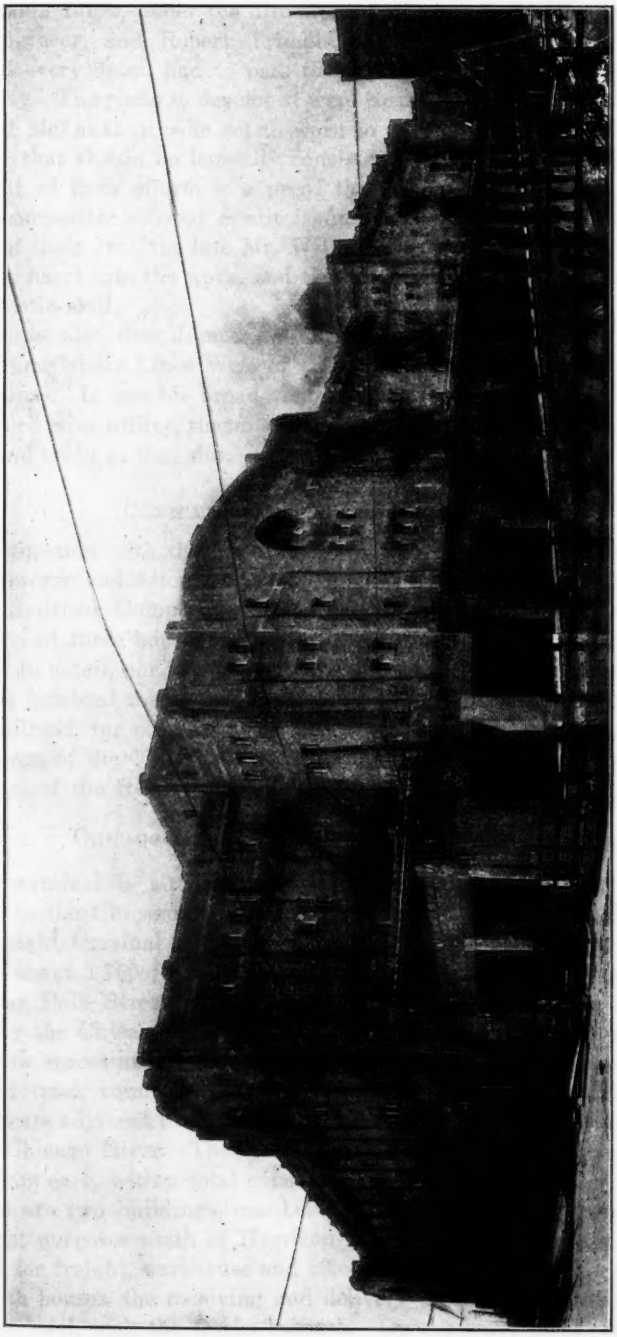


FIG. 64.—VIEW OF COMPLETED FREIGHT TERMINAL OF THE PENNSYLVANIA RAILROAD IN CHICAGO, ILL.

The general design of the building was prepared by the engineers of the Pennsylvania Lines, under the direction of Thomas Rodd, M. Am. Soc. C. E., Chief Engineer, and Robert Trimble, Chief Engineer of Maintenance of Way, and every detail had to pass the test of cold, logical scrutiny as to its practicality. The plans so developed were turned over to the architects, Messrs. Price and McLanahan, who set to work to develop the outward expression in a manner that should be logically consistent, without any sacrifice of beauty. The result of their efforts is a proof that utility and beauty are not necessarily incompatible. Great credit is due them, and, particularly, the senior member of their firm, the late Mr. William Price. The design is largely his—he put his heart into the work, and the accomplishment is a fitting monument to his artistic skill.

Credit is also due James J. Turner, Senior Vice-President in charge of the Pennsylvania Lines West of Pittsburgh during the construction of this freight-house. It was his broad vision of a structure in which beauty should be combined with utility, that made it possible for the engineers and architects to plan and build as they did.

Contemporary Freight Developments

In connection with the new Union Station development, it was necessary for the Chicago and Alton Railroad Company and the Chicago Burlington and Quincy Railroad Company also to rebuild their freight-houses. A brief description of these houses is appended, without any attempt to discuss these terminals in detail, nor to make any analysis of their distinctive features. The speaker is indebted to H. T. Douglas, Jr., Chief Engineer of the Chicago and Alton Railroad, for plans of their buildings, and to W. T. Krausch, Engineer of Buildings of the Chicago Burlington and Quincy Railroad, for plans and a description of the freight terminal of that Company.

Chicago and Alton Railroad Freight Terminal

This terminal is situated between Van Buren Street and Polk Street, adjacent to the Chicago River. A location plan is shown in Fig. 65. The entire freight terminal occupies what is approximately a right triangle with one side about 1 750 ft. long, parallel to the Union Station tracks, and one side, along Polk Street, 475 ft. long, the hypothenuse of the triangle being formed by the Chicago River. The track entrances to the site are limited to two narrow spaces at the apex and the right angle of the triangle, there being one main track connection at the apex and two at the right angle. The buildings are adjacent to the long side, with a team yard between the buildings and the Chicago River. The terminal has 32 tracks, with a capacity of from 2 to 24 cars each, with a total capacity of 460 cars.

There are two buildings, one being a two-story building used exclusively for freight purposes south of Harrison Street and the other a six-story building used for freight, warehouse and office purposes north of Harrison Street.

In both houses, the receiving and delivery platforms and teamways are on the street level, with the tracks beneath. On the lower level are seven tracks

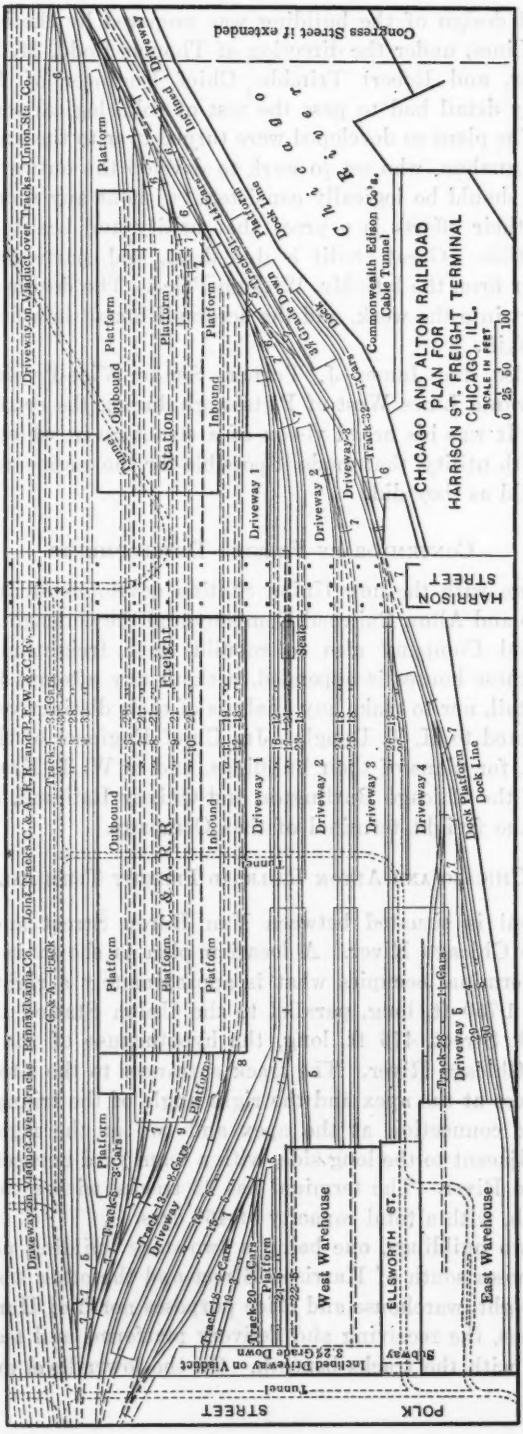

CHICAGO AND ALTON RAILROAD
PLAN FOR
HARRISON ST. FREIGHT TERMINAL
CHICAGO, ILL.
SCALE IN FEET
0 25 50 100
Congress Street if extended
Chicago River
Commonwealth Edison Co's. Cable Tunnel
Dock Line
Passenger Station
Outbound
Inbound
Platform
Driveway 1
Driveway 2
Driveway 3
Driveway 4
Driveway 5
Driveway 6
Track 38
Track 28
Track 20
Track 18
Track 16
Track 15
Track 14
Track 13
Track 12
Track 11
Track 10
3 Cars
4 Cars
HARRISON STREET
Freight Station
Tunnel
Scale
Dock Platform
Dock Line
West Warehouse
East Warehouse
ELLSWORTH ST.
Subway
Inclined Driveway on Viaduct
3.25 Grade Down
POLK STREET
Driveway on Viaduct over Tracks—Union Stk. Co.
Joint Tracks C. & A. R. R. and P. F. W. & C. Ry.
Tracks—Pennsylvania Co.
Tracks—C. & A. R. R.

FIG. 65.

for outbound and four for inbound service, the tracks and platforms being continuous through the two houses.

The inbound tracks are arranged in pairs on either side of a 27 ft. 6-in. platform. The outbound tracks are arranged in two groups of three and four tracks, respectively, separated by a platform 31 ft. 6 in. wide. There is also a 10-ft. platform between the inbound and outbound tracks. Each building has a double driveway on the street floor, opening from Harrison Street. In the building north of Harrison Street the driveway continues beyond the building on a viaduct extending to Van Buren Street. In the other building, the driveway extends about 40 ft. beyond the platforms, in order to furnish a turning place for trucks. Provision has been made for a future driveway on a viaduct above the tracks along the west side of each building.

South Building

On the street level south of Harrison Street are two parallel buildings 460 ft. long, the outbound house being 38 ft. wide and the inbound house 46 ft. wide, with a 64-ft. driveway between them. Longitudinal bays are 20 ft. wide with steel rolling doors in each bay on the driveway side. Steel construction is used for the lower, or track, story, the framing of each building consisting of two rows of wall columns supporting transverse plate girders so that the freight-house is unobstructed.

On the platforms at both street and track level are tracks of 2-ft. gauge for the cars of the Illinois Tunnel Company. These cars are handled to the tunnels by elevators in deep shafts, there being a single oval shaft, 14 ft. 6 in. by 8 ft. 6 in., in the inbound house and a double shaft, 28 ft. by 8 ft. 6 in., in the outbound house.

Freight is handled between the street and track level by elevators with platforms 10 ft. 6 in. by 17 ft. 9 in., located in every third bay in the outbound house, and every fourth bay in the inbound house.

North Building

North of Harrison Street is the main building, 340 ft. long, with a six-story section 120 ft. deep, having a frontage of 236 ft. on Harrison Street, behind which is a three-story section 220 ft. deep and 153 ft. wide. The second floor is designed for warehouse purposes and the third to sixth floors for general offices of the railroad. Steel frame construction is used throughout. Under the six-story building the foundations are cylindrical caissons, sunk to hard-pan, at a depth of about 60 ft. For the three-story section, wooden pile foundations are used. Freight is handled between the floors by eleven 2-ton automatic elevators, with platforms 9 by 17 ft.

Chicago, Burlington, and Quincy Railroad Freight Terminal

The new freight terminal facilities, now under construction, will consist of an inbound and an outbound freight-house, team tracks and team-track facilities, situated east of Canal Street, between Harrison Street and Twelfth Street.

The house facilities between Harrison and Polk Streets will consist of a two-story and track-level inbound house, having an average width of 70 ft. and a length of 796 ft., and a two-story and track-level outbound house, 112 ft. wide and 796 ft. long. The width of the first, or receiving floor, at the street level of the outbound house will be only 62 ft.

Between the inbound and outbound houses will be a driveway, 57 ft. wide, connecting with the viaducts at Harrison and Polk Streets, and an independent driveway, 50 ft. wide, connecting the house with Canal Street and Harrison and Polk Street Viaducts. Although the structures are now being constructed with three floors, the ultimate development of these facilities will consist of six-story improvements.

House facilities south of Polk Street consist of a one-story inbound house, 62 ft. wide by 400 ft. long, and an outbound house of the same size connecting with the track-level floor of the structures north of Polk Street.

The design of the structures north of Polk Street provides for caisson foundations extending to solid rock. The superstructure is of structural steel, encased in concrete, and of reinforced concrete construction with brick walls and rolled steel sash.

The design of the first floor and of the columns for the track level and first floor, provide for the use of structural steel, in order to reduce the size of the columns in the freight-house proper, and to permit of developing improvements or changes for the handling of freight between the track level and first floor at any future time, should this be desirable.

The design of the structures south of Polk Street calls for reinforced concrete with structural steel roof trusses, steel sash and steel rolling shutter doors. The track-level floor and the first floor of the structures will be used exclusively for the handling of less-than-carload freight. The second floor of the inbound house will be used for storage. Part of the second floor of the outbound house will be used as a local freight office and record storage room for the local freight office. The remaining part will be used for storage purposes. When the structure is developed into a six-story structure, the upper three floors will also be used for storage purposes.

All less-than-carload freight will be handled to and from teams and trucks, on the first or street-level floor, and will be raised and lowered from and to the track level or freight-car floor by automatic electric elevators. There will be a total of 27 elevators for the full development with platforms 9 ft. by 17 ft. 6 in., with a capacity of 5 tons.

The structure south of Polk Street, at the track level, will be used for the handling of tunnel freight and for car loading. Tunnels, tunnel shafts, and tunnel elevators have been installed for the handling of freight.

Driveway doors are of a cross-folding type 16 ft. wide in the clear. This width of door will admit of at least two trucks backing up to each door. The inbound house has 34 delivery doors, the outbound house has 71 receiving doors. The inbound house will also be provided with a large refrigerating room for handling of perishable freight.

Sprinkler Tower
CHICAGO, ILLINOIS
PERMANENT HARRISON STREET
FREIGHT TERMINAL

CHICAGO, BURLINGTON AND QUINCY R.R.
CHICAGO, ILLINOIS
PERMANENT HARRISON STREET
FREIGHT TERMINAL
Low Line of Top of Roof Slab
5th Floor Line
4th Floor Line
3rd Floor Line
2nd Floor Line
1st Floor Line
Track Level Story Floor
High Line
Top of Rail
City Datum
Boiler Room Floor Line
Lot Line
Sprinkler Tower
Bridge
Inbound
Outbound
Drive way
Driveway
Tunnel
Boiler Room Floor
CANAL STREET
Lot Line
West Polk Street Lot Line
FUTURE DEVELOPMENT
Future 3rd Floor Line
Building Line
PRESENT DEVELOPMENT

FIG. 66.

Both houses are provided with improved platform scales with platforms 6 by 8 ft. and of 10 000 lb. capacity. There will be 49 scales in the two houses. All scales in the outbound house will have automatic dial attachments. Cranes for the handling of heavy materials are provided at each house.

The inbound house facilities are now completed and being used as a temporary outbound freight-house and will be used as such until the new outbound house is completed in the latter part of 1924.

Construction work on the new outbound house has been started and will be rushed to completion. The car capacity on the inbound and outbound houses will be 314 cars.

Team tracks and team-track facilities, which are nearing completion, are situated between Polk Street and Twelfth Street. These team tracks have wide and spacious driveways, modern scale installations, and are accessible by driveway approaches from Canal and Clinton Streets. The capacity of the team tracks is 168 cars.

Fig. 66 is a general cross-section at Polk Street showing present and future developments. Plans for the part south of Polk Street are not available.

TENTATIVE SPECIFICATIONS FOR STEEL HIGHWAY BRIDGE SUPERSTRUCTURE: SUBMITTED AS A PROGRESS REPORT OF THE SPECIAL COMMITTEE ON SPECIFICATIONS FOR BRIDGE DESIGN AND CONSTRUCTION

Discussion*

By Clarence W. Hudson, M. Am. Soc. C. E.

Clarence W. Hudson,† M. Am. Soc. C. E. (by letter).‡—The writer is not satisfied with the unit stresses adopted by a majority vote of the Committee. He believes that under the specifications for material as adopted that a variation in the strength of the material of as much as 40%, that is 20% either way from a mean, is entirely probable. The significance of this lack of control of quality is that under the method prescribed for taking test specimens an engineer cannot control his material and must protect himself by low unit stresses. A compressive unit stress of 13 000 lb. per sq. in. for short column lengths and decreasing properly for longer lengths, should not be exceeded. It would also be well to limit the tension unit stress to 15 000 lb. per sq. in.

The shearing unit stress of 12 000 lb. per sq. in. is not only too high, but is not in harmony with the other unit stresses adopted by a majority vote of the Committee. If 16 000 lb. is a proper unit stress in tension, not more than eight-tenths of this, or 12 800 lb., is a maximum permissible unit shear. During 1923, the writer has had a number of tests made to determine the shearing strength of structural steel, and these tests have shown that the shearing strength of steel is about seven-tenths of its tensile strength. If, however, the shearing strength is taken as the conventional eight-tenths of the tension, that is, 12 800 lb., then it must be borne in mind that the average shear on a girder web is exceeded by the maximum by as much as 30% in many cases, according to the law of shear distribution in flexure. It would appear, therefore, that 10 000 lb. per sq. in. average shear on the net section of a web-plate corresponds with 16 000 lb. on the net section of the tension flange.

The writer is disappointed that a Committee representing the American Society of Civil Engineers, the most conservative group of engineers in America, should recommend such high unit stresses for steel of the quality specified for bridges.

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* This discussion (of the Tentative Specifications for Steel Highway Bridge Superstructure, published in this number of *Proceedings* and to be presented at the meeting of November 7, 1923) is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† Cons. Engr., New York, N. Y.

‡ Received by the Secretary, June 21, 1923.

THE DESIGN OF EARTH DAMS

Discussion*

By Messrs. Caleb Mills Saville, Fred A. Noetzli, and C. S. Jarvis.

Caleb Mills Saville,† M. Am. Soc. C. E. (by letter).‡—The late Frederic P. Stearns, Past-President, Am. Soc. C. E., one of the most eminent and successful builders of earth dams, once said: "Good engineering requires that in dam building, as in other work, the problem should be studied locally, and that the type of dam adopted should be that best suited to local conditions."

Mr. Justin has summarized quite clearly the methods which must be used in the solution of some of the problems connected with the construction of earth dams, if such structures are to be safe. He has brought together in compact form the deductions made by experts from the results of classical studies of the phenomena relating to the flow of water through permeable materials, and, for convenient use, has epitomized the principles which engineers experienced in the construction of earth dams have found to be most effective.

The criteria proposed by the author are sound, they are stated concisely and clearly, and the diagrams, supported by the numerical examples, serve to make this paper a valuable contribution to the literature on the subject.

The effect of the nature of the materials used and their relationship to the formation of a satisfactory embankment, especially on a permeable foundation, is well brought out, and if applied carefully and judiciously under experienced supervision, should go far toward securing a safe dam. As a general rule, however, the writer has found it more conducive to peace of mind to design, where possible, against the probable passage of water, rather than rely too much on underground conditions to minimize that occurrence.

The writer believes that a properly designed earth dam, carefully built of suitable materials, on a proper foundation, is the safest of structures for holding back water. The theoretical conditions, so well stated by the author, are excellent for the consideration of the experienced dam builder, but, like edged tools, are rather dangerous playthings in the hands of the unskilled men.

Although the writer is somewhat skeptical of placing too great dependence on theoretical considerations—which, at the most, are suitable only for general application when dealing with underground conditions, where failure may mean loss of life and property—his criticisms are made in no captious spirit, but merely to sound a note of warning.

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* Discussion of the paper by Joel D. Justin, M. Am. Soc. C. E., continued from August, 1923, *Proceedings*.

† Mgr. and Chf. Engr., Board of Water Commrs., Hartford, Conn.

‡ Received by the Secretary, May 11, 1923.

For high earth dams, such as the author assumes in his numerical examples—except under exceptional conditions such as those at the North Dike of the Wachusett Reservoir and at the Gatun Dam of the Panama Canal—the writer is much more favorably disposed toward the methods followed in building the Wanaque Dam, in Northern New Jersey, and the Scituate Dam, at Providence, R. I., where core trenches have been excavated to rock and are being refilled with soil or concrete, than to stifle conscience with mathematical formulas on account of the higher cost of the more conservative method.

In the Wanaque Dam* a core trench, 20 ft. wide, 900 ft. long, and with a maximum depth of 90 ft., was constructed across the valley, in order to found the concrete core-wall on rock. This dam is 65 ft. above the original surface of the valley, and is founded for the most part on clay, gravel, and sand, generally overlying deposits of sand.

For the Scituate Dam, at Providence, R. I., a trench, at least 80 ft. wide at the bottom, was excavated to rock, and in it a soil cut-off wall, the full width of the trench, was constructed. This wall was extended to the original surface of the ground, from which it tapered to a width of 15 ft. at the top, 90 ft. above. This dam has a maximum height of about 100 ft. above the valley surface which is underlaid for the most part with fine sand and gravel.

It is greatly to be hoped that Arthur H. Pratt, and Frank E. Winsor, Members, Am. Soc. C. E., Chief Engineers, respectively, of these two dams, will contribute of their valuable practical experience to the discussion of this paper, and incidentally correct any misstatements by the writer.

The author recognizes the lack of uniformity in strata found under actual conditions, and makes allowance for it in his choice of coefficients. This is only common prudence, as it is seldom that deductions of value can be based solely on theoretical considerations, especially in the Northern States, where glacial action, ordinarily, has so mixed up the underlying materials.

To the author's statements of principles governing the safe construction of earth dams, the writer desires to add some experiences that have come under his observation in dealing with dams for which impervious cut-off walls could or could not have been used with propriety.

The condition mentioned by the author and illustrated by him in Fig. 5† is quite similar to that which obtained in one of the experimental hydraulic-fill dams used in studies for the construction of the Gatun Dam.‡ In connection with these studies, miniature dams (Figs. 39 and 40) were built on a scale of one-twelfth of the section proposed for the Gatun Dam, omitting the extreme tail end. These dams were about 75 ft. long, 6 ft. wide on top, and 12 ft. high. They were constructed with materials similar to those to be used in the dam itself and placed by similar methods.

Two of these dams were built; in one, the material pumped was deposited on the down-stream face and allowed to flow to the up-stream side, where the finest material would be deposited, with gradations back to the down-stream

* *Engineering News-Record*, July 20, 1922, p. 94.

† *Proceedings*, Am. Soc. C. E., May, 1923, p. 863.

‡ Described in the Report of the Isthmian Canal Commission for 1908, Appendix E, pp. 139 *et seq.*

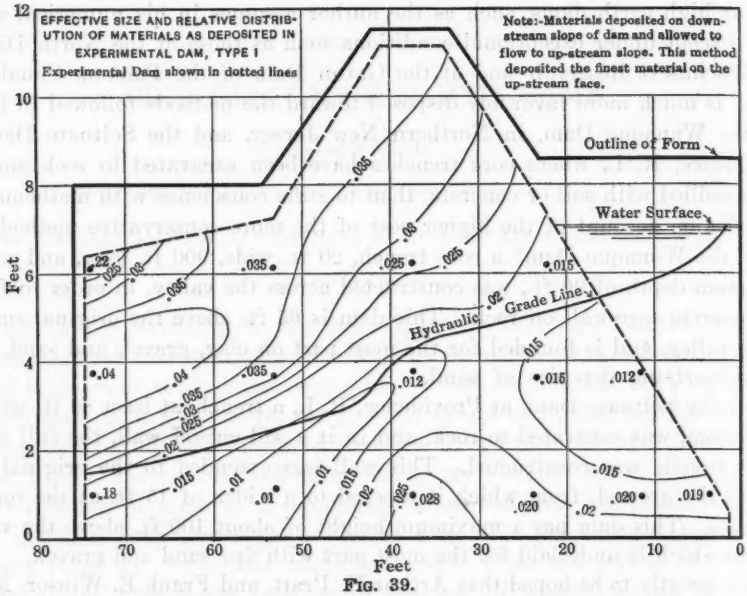
EFFECTIVE SIZE AND RELATIVE DISTRIBUTION OF MATERIALS AS DEPOSITED IN EXPERIMENTAL DAM, TYPE I
Experimental Dam shown in dotted lines
Note:-Materials deposited on down-stream slope of dam and allowed to flow to up-stream slope. This method deposited the finest material on the up-stream face.
Outline of Form
Water Surface
Hydraulic Grade Line
Feet
Feet

FIG. 39.

slope. By this method the most impervious part of the dam was that exposed directly to the water. The practical objection to such a method is, of course, evident.

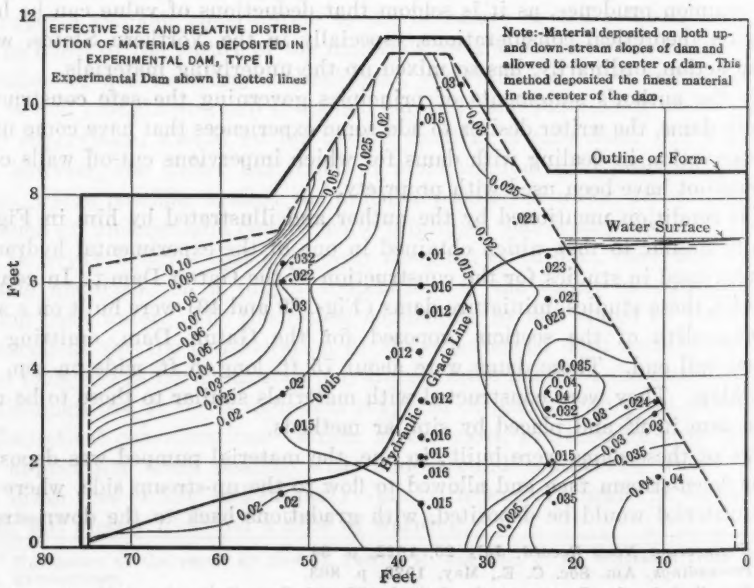
EFFECTIVE SIZE AND RELATIVE DISTRIBUTION OF MATERIALS AS DEPOSITED IN EXPERIMENTAL DAM, TYPE II
Experimental Dam shown in dotted lines
Note:-Material deposited on both up- and down-stream slopes of dam and allowed to flow to center of dam. This method deposited the finest material in the center of the dam.
Outline of Form
Water Surface
Hydraulic Grade Line
Feet
Feet

FIG. 40.

In the other dam the materials were deposited on both slopes and allowed to flow toward the center, where the finest materials were deposited, making this the most impermeable section.

The nature of the materials deposited and their location was ascertained by using an open-ended pipe driven to the required depth, and the location of the line of saturation was found by using driven-well points, checked by glass gauges on the outside of the tank. The segregation of the materials is shown on Figs. 39 and 40.

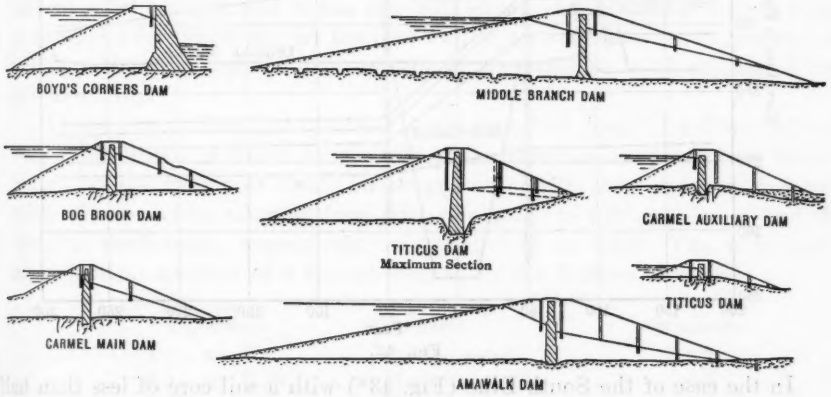

FIG. 41.

The author's diagrams, illustrating the position of the slope of the line of saturation under various assumed conditions, are interesting and instructive. For practical illustrations of these principles, the writer would call attention to the reports of investigations for the New Croton Dam and the Jerome Park Reservoir,* undertaken because of certain criticisms of the methods of construction of the parts of these structures that were built of earth. The slope of saturation in these dams, as found by test-pits or borings, is shown on Fig. 41. All these dams had masonry core-walls. The slope of saturation was:

Dam	Slope per 100 ft.
Bog Brook	30 to 40 ft.
Carmel	35 ft.
Middle Branch	21 ft.
Titicus	10.7 ft.
Amawalk	17 to 14.7 ft.

Borings taken at the North Dike of the Wachusett Reservoir in 1907–08 (Fig. 42†) not only indicated quite clearly the slope of the line of saturation, as modified by the nature of the material, but also showed the rise in the ground-water line due to the greater head after the reservoir was filled. The foundation on which the dikes were placed, was more or less permeable, and the

* *Engineering News*, November 28, December 12 and 26, 1901, January 16 and February 6, 1902.

† This diagram was redrawn from another supplied to the writer by the late Mr. Frederic P. Stearns for use in the report on the foundations of the Gatun Dam.

slope of saturation, due to the thoroughly consolidated soil layer, shows a drop of 16 or 18 ft. per 100 ft., with 12 ft. of water behind the dam.

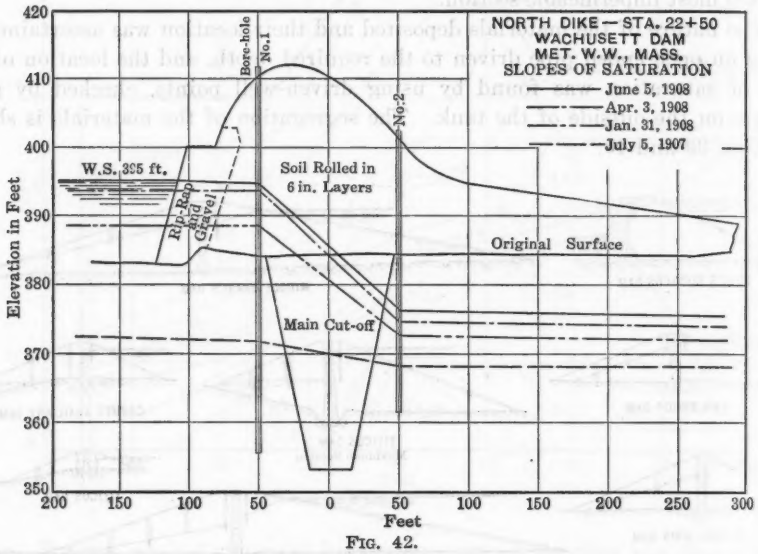

FIG. 42.

In the case of the South Dike (Fig. 43*) with a soil core of less than half the thickness of that in the North Dike, but, in this case, reaching to rock, the slope of saturation was about 40 per 100 ft., with a depth of 25 ft. of water in the reservoir. These conditions are particularly instructive as showing the comparative impermeability of well consolidated, soil cut-off walls and the result of being able to construct a cut-off to rock or to an impervious stratum.

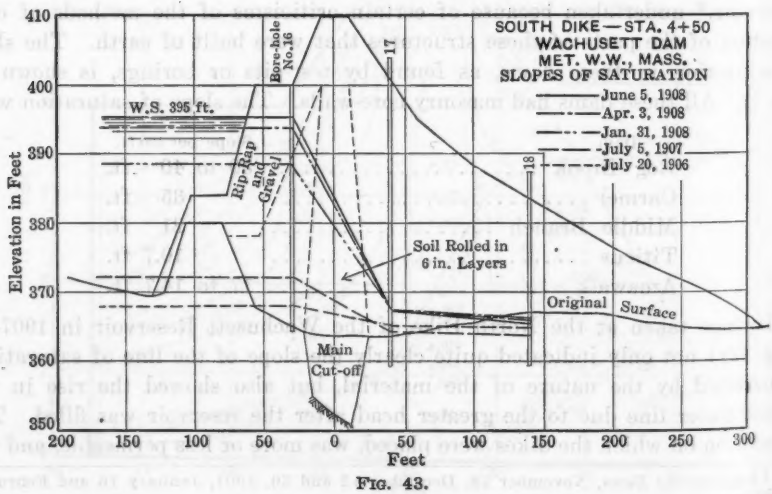

FIG. 43.

* This diagram was redrawn from another supplied to the writer by the late Mr. Frederic P. Stearns for use in the report on the foundations of the Gatun Dam.

The author's discussion of the several formulas deduced from experiment by reliable investigators relative to the flow of water through sands and gravels can indicate, of course, only generalities, and thus serve only as a guide in making deductions from local conditions. These formulas are predicated on uniformity of strata. Such uniformity seldom obtains in actual practice, a condition which the author has well recognized in his remarks on page 872,* his selection of a factor of safety noted on page 905,* and used by him in the numerical example on page 906.*

At the Gatun Dam, this non-homogeneity in under-surface layers, was indicated by borings, and it was also well shown at the sides of a deep trench excavated a few years ago for the core-wall of a rather high earth dam in Connecticut, the character and arrangement of the materials being delineated from actual survey.

At the Gatun Dam, the material is alluvium laid down by sedimentation in very quiet water, as shown by the size of the particles comprising the deposit, which for the most part would be designated as silt, clay, and very fine sand, with effective sizes ranging from 0.01 minimum to 0.03 maximum and uniformity coefficients, respectively, of about 7.25 to 2.6.† The following is a mechanical analysis of a typical sample, by the Bureau of Soils‡:

Diameter, in millimeters.	Conventional name.	Percentage.
1 to 0.5	Coarse sand	0.1
0.5 to 0.25	Medium sand	0.3
0.25 to 0.1	Fine sand	5.0
0.1 to 0.05	Very fine sand	10.5
0.05 to 0.005	Silt	63.5
less than 0.005	Clay	20.8

As to the grading of this material when deposited by the hydraulic process in the experimental dams which were used to determine the suitability of the materials, Figs. 39 and 40, indicate the resulting conditions very clearly, and show the drop in the line of saturation due to the position of the finest particles.

Fig. 44 shows clearly the relation between the quantity of seepage and rate of saturation in the experimental dam under the conditions stated. From this diagram, it appears that the seepage water began to show at the downstream side of the dam in about a week after the head was applied, and reached a rate of constant flow about a week later.

The seepage was measured carefully each day, and the height of the slope of saturation was observed on glass gauge tubes, set at intervals of 4 ft., and connected to perforated pipes laid transversely across the bottom of the tank. The method pursued in this case was similar to that used previously in the determination of the fitness of the materials for the North Dike of the Wachusett Reservoir. A description of the experimental dam used at Gatun has been published.§

* *Proceedings*, Am. Soc. C. E., May, 1923.

† Report, Isthmian Canal Comm., 1908, Appendix E, p. 131.

‡ *Loc. cit.*, p. 171.

§ Report, Isthmian Canal Comm., 1908.

The materials in the valley across which the Connecticut dam, previously mentioned, was to be placed, represent the débris from a country thoroughly worked over by glacial action, some being the deposit from glacial streams and some unstratified till pushed along by the glacier and distributed in the valley. The deposit from the glacial streams, with all the silt and rock flour washed out by the under glacial streams and the running water since that time, are more or less pervious, and range in size from the heavy gravel in the stream bed to the fine sand making the bulk of the deposit in the rock gorge. The unstratified material is on one side of the valley and is practically water-tight, or so nearly water-tight that water passes through it very slowly because of the claylike matrix surrounding the fine rock fragments. This example illustrates plainly the dangers to be guarded against, as noted by the author.*

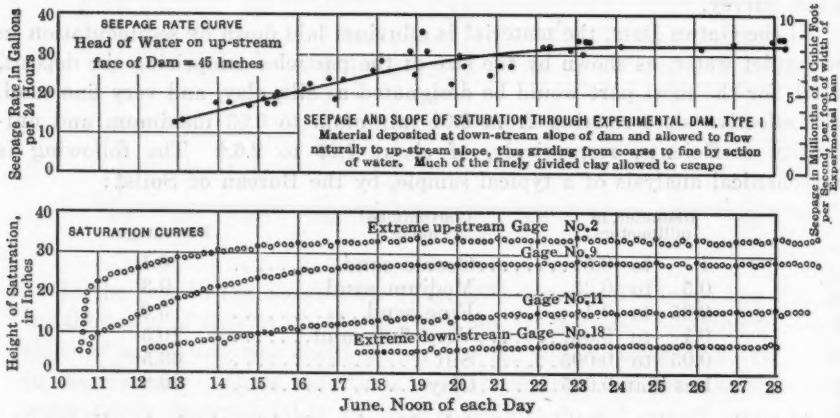
SEEPAGE RATE CURVE
Head of Water on up-stream face of Dam = 45 Inches
Seepage Rate in Gallons per 24 Hours
Seepage in Millionths of a Cubic Foot per Second, per foot of width of Experimental Dam
SEEPAGE AND SLOPE OF SATURATION THROUGH EXPERIMENTAL DAM, TYPE I
Material deposited at down-stream slope of dam and allowed to flow naturally to up-stream slope, thus grading from coarse to fine by action of water. Much of the finely divided clay allowed to escape
SATURATION CURVES
Extreme up-stream Gage No.2
Gage No.9
Gage No.11
Extreme down-stream Gage No.18
Height of Saturation, in Inches
June. Noon of each Day

FIG. 44.

A dam with a suitable cut-off trench founded on unstratified material could be made safe at comparatively small expense, whereas with material, such as the glacial deposit which lies on the opposite side of the valley, it would be folly to take any chances, especially with a high dam, a large volume of water, and a populous community below. As to the up and down-stream slopes, the character of the materials locally available must govern. Materials from deposits of unstratified glacial till like that just described when exposed to water, will not stand on nearly as steep a slope as the heavy gravel deposits. The safest and most impermeable embankment, with or without a masonry core-wall, is formed by placing a sufficiently thick layer of well-consolidated top-soil in the center of the dam, and extending it down to an impermeable stratum or to a depth sufficient to form an effective barrier against underflow or "piping". Outside of this core should be placed material similar to the "till" described, if available, which should be spread in layers and well rolled. On this material, a layer of the "heavy gravel" sufficiently thick will give stability to the whole structure. An approximation to such a cross-section is obtained by the hydraulic process, when suitable materials are available and the dam section is ample to prevent the occurrence of freaks and flaws, which are not

* *Proceedings*, Am. Soc. C. E., May, 1923, p. 872.

guarded against so easily as by the previous method, although, by it, under experienced manipulation, perfectly safe and satisfactory dams are constructed at much less cost than can otherwise be had. In building dams, as in other engineering structures on which protection of life and property is dependent, "safety first" is ultimately the best economy.

The determination of the slope to be used on the up-stream face of the dam, as indicated by the author, is a most important feature, as regards stability. Top-heavy embankments, that is, those with too steep slopes, are a source of weakness and possible danger to the integrity of the dam, whether they are in the dam itself or in the natural hillside on which the dam abuts. With the frictional resistance of the material weakened by the water below and the dry weight pressing down from above, all the elements are present to cause a slide, if the angle of repose of the material in its wet state is not sufficient to counteract it. The troublesome slides in the deep cuts of the Panama Canal are well-known examples of such a cause.

It must be recognized that there is a difference between the pushing out of an embankment due to the weight of a semi-fluid mass behind—as may happen in a hydraulic-fill dam—and when the bank slides due to its own unsupported weight. Examples of the former will no doubt be mentioned by those who have made a particular study of these phenomena. An example of the latter is the slipping of a part of the water-side face of the north dike of the Wachusett Reservoir in April, 1907.* Note of this happening is also found in the technical press of that time. Through the courtesy of the late Mr. Stearns, a cross-section of this slide was used in the report of the Gatun Dam investigations,† and is here reproduced as Fig. 45. The writer has observed steep

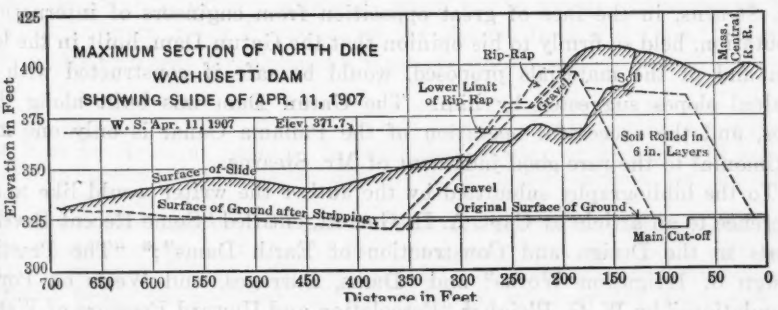

FIG. 45.

hillside slopes, composed of coarse, clean gravel standing perfectly stable in their natural condition, which have slid down after exposure to the action of water, for instance, when a reservoir has been filled.

In the general presentation of this paper, the author has referred particularly to the conditions of water flow through or under dams, and, as the same rules for investigation apply, it is perhaps unnecessary to mention the special

* Described in the Seventh Annual Report, Metropolitan Water and Sewerage Board of Massachusetts, 1907.

† Report, Isthmian Canal Comm., 1908, Appendix E, Plate 134.

cases of water finding its way around the end of a dam. In a locality worked over by glaciers, as in the northern part of the United States, there are many thick deposits of coarse sand and gravel through which water will pass with comparative ease. Some of these are lacustrine deposits; others are due to the wash of streams which flowed from receding glaciers, and others, known as "eskers", have been caused by the wanderings of sub-glacial streams. The first of these are usually thick deposits having more or less uniformity; the others are of irregular composition, resembling lens-like deposits of very coarse and clean gravel surrounded by fine sand. Usually, the "eskers" are regular ridges having great similarity to a railroad embankment. In many cases, present-day streams have cut channels to a considerable depth across these natural embankments, which, at first sight, seem to offer an excellent opportunity for a dam site.

Several failures or part failures have come under the writer's observation because of the percolation of water around the ends of a dam, through the loose material of the "esker", and he desires to emphasize the necessity of investigating the material into which the dam abuts as carefully as that under the dam, if the valley is not to be sealed by an impassable cut-off wall extending across it and uniting with rock at every point.

In commenting further on the author's Criterion 3, "up-stream and down-stream slopes", it is perhaps unnecessary to state that, even with the best materials, workmanship, and foundations, the earth embankment of a dam may slip from the sides if the slopes are too steep, and such an embankment would not be as stable as one of poorer materials and workmanship, on a less firm foundation, but with slopes reduced more than to offset the other disadvantages. It was on the basis of these principles, which he knew so well, that the late Mr. Stearns, in the face of great opposition from engineers of international reputation, held so firmly to his opinion that the Gatun Dam, built in the location and of the materials proposed, would be safe if constructed with the gradual slopes suggested by him. The Gatun Dam was built along these lines, and the successful operation of the Panama Canal is only one more testimonial to the rare good judgment of Mr. Stearns.

To the bibliography submitted by the author the writer would like to add reference to an article by Capt. A. H. Garrett, entitled "Some Recent Developments in the Design and Construction of Earth Dams";* "The Practical Design of Irrigation Works" and "Dams, Barrages, and Weirs on Porous Foundations" by W. G. Bleigh;† "Percolation and Upward Pressure of Water" by Capt. W. A. Mitchell, Corps of Engineers, U. S. A.; and "The Control of Water" by the late Philip à Morley Parker,‡ M. Am. Soc. C. E.

FRED A. NOETZLI,§ ASSOC. M. AM. SOC. C. E. (by letter).‖—The author gives much valuable information which will be helpful for supplanting rule-of-thumb by more scientific methods for designing dams of the earth-fill type.

* *Royal Engineers Journal*, Royal Engineers Inst., June, 1911.
† *Engineering News*, December 29, 1910, p. 708.
‡ Chapter on "Dams and Reservoirs."
§ San Francisco, Calif.
‖ Received by the Secretary, July 2, 1923.

Mr. Justin cites six criteria which must be met in order that an earth dam may be considered safe.

This gives rise to the question: How much is the factor of safety of an earth-fill dam? Is a structure which meets the author's six criteria just safe enough, or is there a mathematical expression for a so-called "factor of safety"? The writer would like to obtain the opinion of other engineers on this question, in order to arrive, if possible, at a method of comparing the safety factors of earth-fill and masonry dams.

The writer would suggest that a seventh criterium be added, as being of vital importance to the usefulness of an earth dam, namely, that the seepage losses through, under, and around the dam be limited to a permissible quantity. The writer knows of several earth dams which seem to be safe, but which leak to such an extent as practically to destroy their usefulness.

Mr. Justin gives formulas and other data for locating the position of the line of saturation, and also for calculating approximately the seepage losses. The difficulty in applying such formulas will lie in the selection of the proper coefficients, which is a difficult task with an earth-fill dam in which the grading of the effective size of the fill material may vary considerably throughout the dam. Theoretical calculations such as those given in the paper, therefore, may be of interest from a purely scientific point of view, but, as the author rightly remarks, "* * * it is not wise to consider the results of the calculations as precise". However, such theoretical investigations may well serve as a basis on which to establish the practical considerations for the construction of earth-fill dams.

Such further considerations in most cases will inevitably lead the investigator to the great "hydraulic principle" which was so clearly expounded by Mr. George L. Dillman in his discussion on the Morena Rock-Fill Dam.* It may not be amiss to repeat Mr. Dillman's masterly statement:

"* * * Construct one impervious surface, and build the rest of the structure to support that surface. If this surface should not be water-tight, make it as nearly so as possible, in order that seepage or leakage will not be allowed to accumulate pressure against some other surface, or do other damage in getting away.

"In the case of masonry or concrete dams, the particular part to make tight is the up-stream face. If this is tight and supported, the result will be a dam; otherwise, a failure. This support is: (1) Solid masonry or concrete, the result being the so-called uniform-sectioned type; or (2) Buttresses of masonry or concrete, resulting in the multiple-arch dam—safer and more economical; or (3) A mass of loose rock [or earth], * * *, resulting in a stable structure."

In accordance with the "hydraulic principle", a water-tight diaphragm, therefore, should extend over the total length of the dam near its up-stream face. This evidently would be also a very suitable way of meeting the author's important Criterion 2.

The writer has recently designed an earth-fill dam that is to have a somewhat novel type of impervious diaphragm, or composition core-wall, which is believed will be satisfactory and, at the same time, very economical. This

* *Transactions*, Am. Soc. C. E., Vol. LXXV (1912), p. 52.

diaphragm will consist of two inclined slabs of reinforced gunite with a layer of asphalt between them. It will be cast in place on a slope of about 1½:1, in the up-stream half of the dam. Fig. 46 shows a typical cross-section through this proposed dam. The construction will proceed about as follows: A trench extending to impervious material will be excavated between the up-stream face and the center line of the dam, and a low concrete wall of suitable thickness will be built so as to insure safe contact with the impervious foundation material.

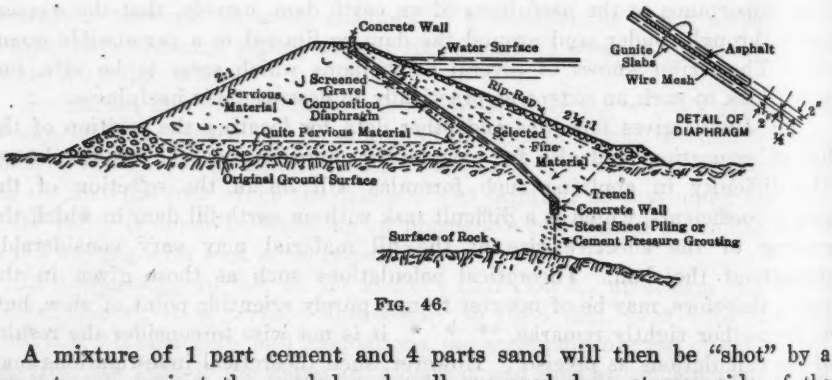

FIG. 46.

A mixture of 1 part cement and 4 parts sand will then be "shot" by a cement gun against the graded and well prepared down-stream side of the trench and up to the original ground surface. Fine wire mesh will be used for reinforcement. A ½-in. layer of hot asphalt will then be applied either by brushes or by a spraying device. On the asphalt, a second layer of gunite will be placed, suitably reinforced like the first layer. Each of the gunite slabs will be about 2 in. thick.

The earth embankment will then be built up with a slope of about 1½:1, and the gunite and asphalt membrane placed on this slope in a manner similar to that just described. The dam is to be completed by placing selected fine material on the up-stream side against the diaphragm, and by paving or rip-rapping the up-stream face for protection against waves.

Such a diaphragm with a continuous sheet of asphalt between two layers of reinforced gunite is comparatively inexpensive, the estimated cost being about 35 cents per sq. ft. of area covered. In some cases, it may be more economical to use reinforced concrete slabs instead of gunite. It will always be of advantage to build the diaphragm slightly curved in an up-stream direction. Any settlement of the fill material will then have the tendency to introduce compression in the concrete or gunite slabs.

It is believed that, in addition to low cost and imperviousness, such a composition diaphragm has the following advantages over other types of concrete core-walls:

1.—It is extremely flexible, and a comparatively large settlement of the earth embankment may occur without producing other than hair cracks in the reinforced gunite. On account of being hermetically sealed, the asphalt will probably retain its plasticity for many years, at least until the embankment

has its final set, and cracks in the asphalt will probably not occur under slight movements during this period.

2.—Inasmuch as the membrane is always under considerable compression due to the weight of the earth-fill over it, the asphalt would be pressed into and seal any small cracks that might occur in the gunite slabs. Any bending or twisting of the membrane would tend to cause a sliding movement of the two gunite slabs over each other, which no doubt would tend to fill with asphalt any cracks that might exist in the gunite.

3.—Such a gunite-asphalt membrane has practically all the advantages of other known types of masonry cores, although it costs little more than the form work for concrete core-walls.

C. S. JARVIS,* M. AM. SOC. C. E. (by letter).†—The author has presented with unusual clearness the criteria and the basic principles to be observed in the design of earth dams, and has clothed a prosaic subject so attractively as to make it of great value to the young engineer as well as to those of ripe experience. It is of special value to have all interested parties understand from the beginning that partial cut-off or core-walls do not prevent seepage, and may not reduce it materially, but merely define the areas through which the escaping waters may pass. It is remarkable what an increased sense of security is established in a community dependent on such a structure when it is known that the path of the water has not only been deflected through materials at great depth, but also greatly increased in length, thereby reducing both the flow and the pressure at the point of emergence.

One method of obtaining appreciation of correct design is to review examples illustrative of the most common errors.

Example No. 1.—A group of practical irrigation farmers having need of storage to supplement the normal mid-summer flow undertook to deepen the outlet channel of a mountain lake, and to construct an embankment over the outlet culvert to impound the lake to a higher level. As the entire country was either glaciated ledge rock or glacial moraines, it was difficult to find sufficient earthy material to provide a proper core-wall.

Being familiar with the virtues of sod dams in irrigation laterals, they constructed the body of the embankment mainly of meadow sod and gravel, and placed stone rip-rap on both slopes, closed the outlet gate, and returned to their homes for the winter, intending to return in the following spring to complete the project.

Apparently, no one felt much concern regarding this dam until early the next summer, when an unprecedented flood heralded the failure of the dam. Although no lives were lost, the damage inflicted on highways, bridges, and farm lands, together with the loss of the retained water, made it an epochal disaster. It seemed impossible to fix responsibility; the organization seemed as unstable as the structure.

Several years later, while the writer was engaged in building a substantial rock and earth-fill dam at the place just described, he had to clear the

* Highway Engr., U. S. Bureau of Public Roads, Phœnix, Ariz.
† Received by the Secretary, July 5, 1923.

dam site of such remnants as remained from the old sod dam, which had reduced to the consistency of sawdust or compost.

Example No. 2.—A type of earth dam that fulfills all the criteria listed by the author, may be rendered unsatisfactory because of porous strata beyond the limits of the structure. Obviously, this does not necessarily endanger the dam, but it may prove to be a useless project until the rock seams or porous deposits have been sealed by an earth blanket. This element is of great importance in districts where volcanic ash and lava abound, and in river valleys subject to torrential floods from tributaries, and warrants special investigations by borings and test pits.

Example No. 3.—The writer knows of one occurrence that may well be recorded as showing the symptoms of impending failure of an earth dam. (Fig. 47.) Enlargement of an existing structure was in progress, the intended final section being designated by the dotted lines. It is probable that the steep slope of 1¼:1 was not thus designed, but resulted from adding height to the original crest without widening the base.

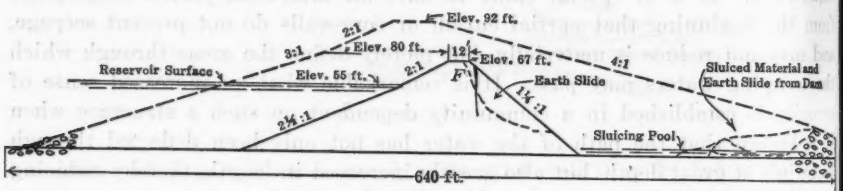

FIG. 47.

It was planned to have the hydraulic fill down stream from the old dam keep pace with the rising surface of the reservoir, but uncontrolled causes of delay resulted in the water being at about Elevation 55 before the sluicing was fairly begun. Within a week after the down-stream pool was formed a longitudinal fissure at point, *F*, Fig. 47, developed in the dam, and, then, without warning, the central section, about 100 ft. in length, with a maximum depth of about 35 ft., slid from the face and came to rest only when it thrust against the rock-fill toe. It then developed that a noticeable seep of several gallons per minute was passing through the pervious sandy stratum at Elevation 46. Figs. 48 and 49 show the site of the slides, sluicing flumes, and banks at Sevier Bridge Dam.

While the structure was in this critical condition, a severe storm occurred, with about a 30-mile wind from the only direction that could cause a maximum wave action. With a fetch of about 10 miles, the wave crests broke on the slope of the dam at a height of 5 ft. The precipitation and the wave lashing increased the seepage at Elevation 46 to 30 gal. per min., and other masses were continually falling into the chasm produced by the sliding section.

When the sluicing flume clogged and overflowed near the weakened section, and suddenly collapsed, as the foundation gave away, there was not much chance of the structure remaining in place. Prompt placing of drain tile and corrugated metal roofing sheets in the bottom of the scar, between the sloughing banks, concentrating the hydraulic fill immediately below this

FIG. 48.—VIEW OF SLUICING FLUMES AND BANKS AT SEVIER BRIDGE DAM, JUNE 16, 1914.

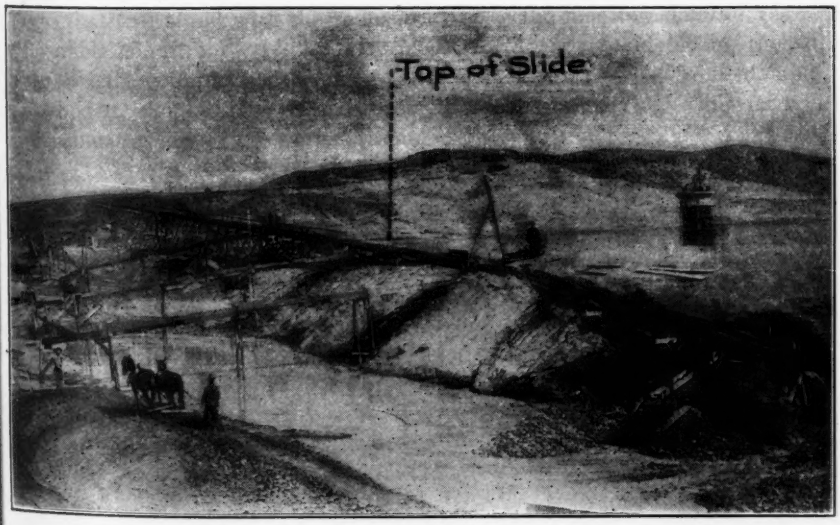

FIG. 49.—VIEW OF SLUICING OPERATIONS AT SEVIER BRIDGE DAM, APRIL 15, 1915.

section, and extending a clay blanket to seal the porous stratum, and an abatement of the storm, all had a pronounced effect, and the project was successfully completed.

At times during subsequent sluicing operations it was discovered that the pool had collected an unusual quantity of fine, unctuous clay. The control gates would then be opened and the slimy sediment would be discharged beyond the dam. This concentration of the finest particles in the deepest part of the sluicing pool is a menace that constantly besets hydraulic-fill dams. Unless great care is exercised, there will be lense-like masses of unstable, quaking material to mark the maximum depth of a summit pool during some period of the sluicing. One has only to examine an uncompleted structure on which work has been suspended, to note great blocks of clay, with cracks extending perhaps 2 ft. in depth, in the deepest trough of the pool. By skillful operation of lateral flumes while sluicing, these deposits may be displaced by the heavier materials and crowded toward the wasteway and disposed of there, or, if desired, the finer particles can be incorporated with the coarser, and such a concentration may be avoided.

Because most of the reservoir dam failures have involved earth construction, an ungovernable fear has been entertained by those living within the areas that would be submerged if existing earth dams were to fail. This prejudice usually weighs against the adoption of this type of structure even where it would serve equally well and cost less than other types. Although there are important sites to be developed, which are not suitable for masonry structures, or where the cost of any structure except an earth dam would be prohibitive, it seems incumbent on the Engineering Profession to design a type that will stand with the same security as the masonry dam affords under favorable conditions. If the criteria set forth and elucidated by the author are strictly complied with, the requirement mentioned is fulfilled, and the earth dam should take its place among great engineering achievements, as permanent as any of the works of man.

THE RIVER AND HARBOR PROBLEMS OF THE LOWER MISSISSIPPI

A SYMPOSIUM

Discussion*

By Messrs. John R. Freeman, W. G. Price, J. A. Ockerson, Sidney F. Lewis, C. W. Chapin and C. McD. Townsend.

John R. Freeman,† Past-President, Am. Soc. C. E. (by letter).‡—It is to be regretted that Mr. Ripley did not give more dimensions, velocities, and other measurements, but followed the customary method of nearly all authors on river and harbor hydraulics, in avoiding the kinetics of these problems and making no attempt at even a crude computation of the magnitude of the forces at work. It was finding omissions of any attempt at real scientific analysis like this that slowly led the writer to the conclusion, after reading almost all that could be found on the subject, that the control of currents is without as yet much of a scientific basis, and in the state of a mechanic art, proceeding slowly by methods of trial and error. That the work of controlling river and harbor currents is still in a stage of development like the work of the old alchemists, before everything was weighed and measured, or like the electrical experiments made in high schools half a century ago, before everything was measured and described in terms of volts and amperes.

During many years past there have been available accurate units of measurements for hydraulic forces. Engineers understand the translation of head into velocity, and can estimate the energy of moving masses of water, 1 000 ft. wide and of any depth, or accurately compute the head and velocity that can be generated in turning it from its course.

Is it not highly probable that all the problems of these jetties, of the currents that approach and run between them and that may or may not dig the channels deeper, are responsive to measurement and mathematical treatment?

Unfortunately, there are far fewer data than are needed on the laws which hold sediments in suspension or on the forces required to break the adhesion of particles of sand and clay to their beds. One seldom finds records of mechanical analyses of the sizes and proportions of the sediments that obstruct a channel, or of the sub-microscopic colloids that may glue them together, or of the molecular physics of adsorption that may have much to do with the stability of sloping banks.

To measure these things may be outside the training of the pilot or dredge captain, or even the construction engineer; nevertheless, they are real forces

* Continued from August, 1923, *Proceedings*.
† Consulting Hydraulic Engr., Providence, R. I.
‡ Received by the Secretary, April 18, 1923.

that must be reckoned with, in order to find the most economic solution for harbor problems and be sure of success.

The cost of the failures mentioned by Mr. Ripley would build and endow a dozen hydraulic laboratories.

W. G. PRICE,* M. AM. SOC. C. E. (by letter).†—In 1922, the writer made a study of Mississippi River construction works and obtained some data which should be of interest to civil engineers.

After forty years, there seems to have been no successful general plan of improvement put into use by the engineers in charge. Old methods are frequently abandoned and new methods used, which are also failures wherever the river has a chance to exert its full force on them. The writer believes these failures are not due to any lack of American engineering ability to cope with the forces of the river. The officers in charge of divisions of the Mississippi River improvement work are frequently transferred to other works, and each new comer usually has a new scheme of improvement. In 1922, assistant engineers indicated to the writer that they felt it to be useless for them to try to work out more successful methods, as each new officer would upset their plans.

In New Orleans, in the Carrollton District, as a result of those changes many blocks of the city were destroyed by the river and a large amount of money was wasted at Plaquemine and at other places where the previous works had been successful.

Long before white men lived in Louisiana the Red and Atchafalaya Rivers, using the force of the moving water and the drift material which it was carrying, built permanent dams.

In order to make these rivers navigable, snagboats were used to open channels through these dams. Many years afterward, the writer noted that in sharp bends of the rivers, the remnants of these dams, were efficient revetments of the banks. Tests made by him in the Mississippi at St. Louis, Plum Point, and New Orleans, and in the Ohio and Tennessee Rivers, near Paducah, indicated that when the river is rising a large quantity of drift material is moving under the surface of the water, and twice in the beginning of a rise in the river, when there was almost no drift on the surface, the writer observed the under-water drift collect and gradually pull down on the anchor rope of a large skiff at Plum Point, and of that of a survey catamaran at St. Louis, and, in each instance, eight men were left floating to be rescued by a steam launch. The boats of the catamaran had water-tight decks. Green sycamore trees roll along on the river bottom and have carried away current meters. The writer believes that, reasoning from the sinking of the catamaran, a successsful plan for using drift material to protect river banks from erosion can be developed.

In 1890, the writer, by request, submitted to the Mississippi River Commission plans for a dam across Red River, at Turnbulls Island, about eight miles from the Mississippi. One plan, which was rejected, was to

* Cons. Engr., Yakima, Wash.

† Received by the Secretary, April 16, 1923.

assist the river to build its own dam by anchoring obstructions to catch the drift. If this plan was to be a success as a revetment in the Mississippi, it would be necessary, where wharves and landing places for steamboats are required, to use, instead, a thick crib mattress revetment reinforced with heavy cribs, to brace steep banks from caving, such as the writer designed and placed in New Orleans Harbor.

J. A. Ockerson,* Past-President, Am. Soc. C. E.—Gen. Beach has given a brief outline of the greatest problem that confronts the country to-day, namely, the improvement and flood control of the Mississippi River.

The Mississippi River Commission has just finished an inspection trip covering the river from Rock Island, Ill., to New Orleans, a distance of about 1 500 miles, where levee building, bank protection, and works of channel improvement received attention.

When the Commission was created, in 1879, it early realized the magnitude of the problems assigned to it for solution, but promptly began systematic work in gathering the much-needed data.

The law provided that the Commission should mature such plans:

"As will correct, permanently locate, and deepen the channel and protect the banks of the Mississippi River; improve and give safety and ease to the navigation thereof; prevent destructive floods; promote and facilitate commerce, trade and the postal service;" also, that "the Commission shall report in full upon the practicability, feasibility and the probable cost of the various plans known as the jetty system, the levee system, and the outlet system, as well as upon such others as they may deem necessary."

There were few if any precedents to follow, in its work of guiding and controlling a stream which carries the drainage from a water-shed of 1 240 000 sq. miles. There were no adequate surveys, or studies of the regimen, that could be used with confidence in the preparation of plans for the regulation and control of the river.

Several years were devoted to surveys between the head-waters and the Gulf of Mexico. These surveys covered in great detail all the elements required for a thorough understanding of the physics of the river, and scientific analyses thereof have been made. Much time has been devoted to the study of outlets and crevasses and their effect on the bed of the river, and the conclusion has been reached that the invariable result is a deposit in the bed of the river which reduces its carrying capacity below the outlet. As a corollary to this conclusion, the Commission adopted the policy of closing outlets on the Lower Mississippi River.

Although these studies have been thorough and exhaustive, a permanent staff of experts is still maintained by the Commission to trace and record the changes that may occur in the regimen of the river, their causes, and the remedy therefor where needed.

Construction work also entered a new field barren of precedent, and many years were devoted to experimental work. In channel improvement, a plan of contracting the river to a width of 3 000 ft. by building pile dikes was adopted. The first dikes, constructed of cottonwood piling, proved to be too

* Cons. Engr.; Member, Mississippi River Comm., St. Louis, Mo.

flimsy. Their stability could only be established by going safely through several cycles of high and low water, and this time element could not be eliminated. They had to be tried out under actual conditions.

In the upper reaches of the river, huge ice floes cut down the dikes. In the reaches above Vicksburg, the excessive bank erosion flanked the dikes and caused their destruction.

In the case of bank revetment, the early willow mats used were found to be too thin, and the fascine mat, 1 ft. or more in thickness, was developed, the mat widths being increased so as to cover the slope of the bank from low water out to or beyond the thalweg line. In later years, concrete mats, both articulated and in large slabs, have been developed and used successfully.

Comment has been made on the slow progress made in revetment work. There are two reasons for this: One is lack of funds, and a more important one is that the supply of willows available will not permit more rapid progress, and, furthermore, it is only necessary to keep pace with the progress of caving. If unlimited funds and materials were available, it would not be economical or necessary to revet the banks more rapidly than the progress of caving demands.

With these experiments and meager appropriations, progress was necessarily slow. Navigation interests could not wait for the completion of the contraction project, and studies were begun by the Commission which resulted in the development of great hydraulic dredges with which a navigable channel is now maintained from Cairo southward. These dredges set the pace for the world. The largest dredge in use at present has a 90-in. centrifugal pump, 36-in. discharge pipe, and its field record shows that it can dig a channel in the river bed 32 ft. wide, 6 ft. deep, and 300 ft. long, in an hour.

The Commission began levee building in 1882, when levees along the Yazoo Basin averaged 8 ft. high, with a crown of 8 ft., side slopes of 1 on 3, and contained 32 000 cu. yd. per mile. Levees up to present standard grade and section in the same district are about 22 ft. high and, with the banquettes, contain about 420 000 cu. yd. per mile. The grade line is 3 ft. above the highest known stage of the river.

As the levees grew larger, changes in methods of construction became necessary, passing through the several steps from wheel-barrows to scrapers, wheel scrapers, drag-line, and, finally, for the great levees, requiring a span of 700 ft., to cover the base of the levee, berm, and borrow-pit, the cableway machine with a 6-yd. bucket has been developed.

There were many things to learn about levee building, which to the novice seems to be merely piling up earth to a sufficient height. Practically all the levees have been built through timber lands. This means a large quantity of clearing and grubbing for the base of the levee and the elimination of roots, stumps, and other foreign matter from the body of the levee. The clean earth is preferably deposited in layers of suitable thickness. Ample shrinkage must be provided for, and sipe water and wave wash must be guarded against, as far as practicable, by a heavy sod of Bermuda grass or by surfacing with concrete. Some have complained that the material used in levee construction has not

been selected. The material along the site on which the levee stands must be used, and the selection of material, to any great extent, is wholly impracticable.

Before levee building began, the great floods covered the delta basins to a maximum width of 65 miles. The reclamation of these basins by building levees has reduced the flood widths to about a mile or two, and this is the immediate cause of an increase in flood stage. There is little, if any, evidence that the floods themselves are growing greater in volume.

In the flood of 1922, which reached a higher stage below Arkansas City than any of its predecessors, more than 20 000 sq. miles of land below Cairo were protected from overflow, although two-thirds of the length of levee were not yet completed up to the adopted grade line.

The present law provides for the protection of the banks of tributary streams, as far as affected by back-water from the Mississippi, and the extension of the levees to the lower ends of the several basins will be continued. In the meantime, the great City of New Orleans must be amply safeguarded, and the fears of the people allayed, by such means as will make the city impregnable to damage from future floods.

Gen. Beach has stated that the Engineer Corps of the Army has had an important share in this great work, in which the speaker heartily concurs; but one must not overlook the civilian engineers under the Commission, and the levee boards, who, year in and year out, have stood loyally by the work, devoting their best energies to solving the intricate problems presented. To them belongs a very large share of credit for such success as may have been achieved. An ounce of their experience is worth a ton of advice from novices who have only recently discovered the Mississippi River.

Rather than discuss any special feature brought out by Gen. Beach, the speaker has given a mere glimpse of the work in which the Mississippi River Commission has been engaged.

Sidney F. Lewis,* M. Am. Soc. C. E.—The speaker has been connected with Mississippi River work, on the Board of State Engineers from 1877 until the present time. It has been his life study. In 1877, after the Reconstruction Period, the Board was confronted with a serious financial condition, and it had to do the best it could with the levee system, which had deteriorated since the Civil War. There were many outlets that could not be closed, as funds were limited, and the best that could be done was to keep certain parts of the State free from overflow. New Orleans, fortunately, was never confronted with any danger from the Mississippi during those periods, for the reason that the river never reached flood stage, owing to overflows north of the city, through breaks in the levees, notably the Bonnet Carré break about thirty miles above the city, on the east bank of the river, which was open from 1874 to 1882. The river did not rise as high as it does to-day at New Orleans, because it escaped elsewhere. With the exception of the flood of 1922, the greatest flood occurred in 1882.

In 1879, the Mississippi River Commission was organized, and a minority of that Commission believed in the use of levees. The disaster of 1882, how-

* Member, Board of State Engrs., of Louisiana, New Orleans, La.

ever, forced the Government to make an appropriation of $5 000 000 for the Mississippi River, of which $1 000 000 was to be devoted to closing breaks in the levees. This was followed by the creation of Levee Districts, previous to which Louisiana was divided into Levee Engineering Districts. There were five Districts along the Mississippi River. To-day, there are seventeen organized Levee Districts in the alluvial districts of the State.

These Districts not only levied *ad valorem* taxes, but had the power to compel planters to make contributions on the crops raised, a certain amount on a bale of cotton, or a barrel of sugar; even oysters were taxed at 50 cents a sack. This forced contribution created considerable revenue, in addition to the regular *ad valorem* tax which was one mill on the dollar throughout the State.

Gradually the levee system was built up, and although there were 252 breaks in 1882 in Louisiana alone, there were only four in 1892. In the flood of 1882, the whole Teche country was practically under water, with Morgan City, Patterson, and Franklin, and the land on both sides of the Atchafalaya River submerged. That is what brought the Government to the rescue.

As to the physics of the Mississippi River, as Gen. Beach has stated, and as may be found in all the literature on the subject, one cannot compare the Mississippi with any foreign river. By its deposit of sediment, it is building itself out into the Gulf of Mexico, and its slope is governed by its fluctuations, from nothing in low water to 0.2 ft. per mile in flood stage. There are a number of bends, due to the sinuosity of the stream, and by the caving of the river bank, they gradually approach one another, when a cut-off across the narrow neck of land between two bends will take place. Cut-offs and outlets destroy the regimen of the stream, until, in course of time, Nature asserts itself; they, therefore, should be prevented from occurring, and the river maintained within its channel. Records show that these bends have moved down stream and that the length of the river has not been appreciably shortened by cut-offs. The distance from the mouth of Red River to New Orleans is practically the same as it was some 200 years ago, although three cut-offs have taken place, one near Red River, and two below, as follows: In 1722, False River cut-off occurred; in 1821, Shreve's cut-off near Red River; and, in 1848, Raccourci, just below Red River.

The speaker received his first impression of the Mississippi River when, in 1872, on his journey through to Washington to attend college, he took the river route *via* St. Louis. Those were the days of palatial steamers, and the passage from New Orleans to St. Louis, in low river, took him 14 days. At that time the speaker saw quite a number of steamers stranded in the upper river between St. Louis and Cairo. After the Civil War, railroads were constructed rapidly, principally in the West, and railroad engineering received the most attention in technical institutions.

In the treatment of the Mississippi the levee system cannot be abandoned, as it is recognized that the levees help the low-water navigation. The Mississippi River Commission had experimented on the bars with jetty dikes and applications similar to those used at South Pass by Capt. Eads, a member

of the Commission, and these had proved a total failure. Finally, the bars were dredged with hydraulic machinery, and, to-day, the low-water channel is better than it has ever been. Boats, drawing 9 or 10 ft., can go from New Orleans to St. Louis during low water. However, there is not much low-water navigation on the river, with the exception of the Mississippi and Warrior Rivers Barge Line and a few Government steamboats.

It is said that the sediment in the Mississippi comes from the Missouri River. A great deal of it comes from the caving of river banks in the bends below Cairo. The Ohio is a mountain stream, and, generally speaking, contributes the high water. Some of the most serious floods were not only from the Ohio, but also from the Upper Mississippi and Missouri. If the distribution of rainfall could be predicted, the necessary grade and section for a complete levee system could be determined; but there can be no complete levee system without bank protection. The revetment of the banks is a tremendous undertaking, for it cannot be done at present for less than $300 000 per mile. Any one familiar with the bends in the Mississippi knows what a big financial problem it is. If money was furnished, these banks could be revetted from Cairo down, thus providing a low-water channel of 14 ft. or more as far as St. Louis, and holding the levees against any flood. The solution of the problem is the revetment of all caving bends. A complete levee system is needed and, to have that, there must be bank protection, otherwise the levees will cave into the river and have to be replaced by larger levees built farther from the river bank.

C. W. CHAPIN,* ASSOC. M. AM. SOC. C. E. (by letter).†—The Mississippi River flood of 1922 established new high-water marks at the mouth of the White River, in Arkansas, and at all gauging stations below this point, whereas, at all stations above the White River, up to and including Cairo, Ill., the high records of previous years still stand. The prevention of breaks in the levee system above Natchez, Miss., during the flood, and the prior raising of levees above this point, with a consequent elimination of great, temporary impounding reservoirs, contributed to this result.

As the construction of the levee system approaches completion and the flood waters are held within bounds, the duration of flood stages will be shortened and the magnitude of floods to be carried to the Gulf will be increased, thus making the problem of their safe discharge more and more difficult.

The Weecama Crevasse, which occurred on April 25, 1922, on the Louisiana side, at a point opposite Natchez, Miss., had a maximum discharge of 623 000 sec-ft., as estimated by the Mississippi River Commission. Water from the crevasse flooded the Tensas Basin, flowed down the Red River, and found an outlet through the Atchafalaya and Mississippi Rivers. This crevasse doubtless prolonged the duration of flood stage in the Mississippi below Red River, and probably reduced its extreme flood stage, because of the large quantity

* Big Creek, Calif.

† Received by the Secretary, April 5, 1923.

of flood water it carried to the Atchafalaya River and thence through that outlet to the Gulf.

The course of events below the mouth of the Red River during this flood offered an interesting study as to what stages might have been reached, had no breaks or crevasses occurred, and as to the bearing of these breaks on the spillway problem. An estimate of probable gauge heights is simplified by the fact that practically no water enters the Mississippi below the Red River.

The Myrtle Grove Crevasse, in the west levee, 35 miles below New Orleans, occurred on April 23; and the Poydras, in the east levee, 12 miles below New Orleans, on April 27, 1922. The effect of the Myrtle Grove Crevasse on river stages was small, as compared with that at Poydras, its discharge being only about 10% of the latter. In some of the following estimated discharges, the two breaks are considered as one, situated at their "center of gravity", approximately 14½ miles below New Orleans and 23 miles below Carrollton, La.

The river rose steadily at Red River Landing, La., and all gauging stations below this point until April 27, the date of the Poydras Crevasse, at which time all previous high-water records had been exceeded, as shown in Table 1. The effect of the Poydras break was felt immediately, the gauge at Carrollton (New Orleans) showing a lowering of 1 ft. within 3 days. The river, however, continued to rise at Red River Landing until May 16, on which date the gauge readings at Red River Landing and at all stations down to and including Donaldsonville, La., exceeded those of April 27, whereas below Donaldsonville, the gauges of April 27 still stand as high-water marks.

The Weecama Crevasse and the connection of the Mississippi to the Red and Atchafalaya Rivers preclude the possibility of determining what effect, if any, the Poydras Crevasse may have had on gauge heights above Red River Landing. Assuming the effect of the crevasse to begin at Red River Landing, its influence below this point can be determined within close limits by plotting gauge relation curves between successive gauging stations. Plotting daily gauges at Red River Landing and Bayou Sara up to April 27 (the date of the Poydras Crevasse), gives a curve showing the relation between gauge heights at these stations with the levees intact below. Producing this curve to the high stage reached at Red River Landing on May 16, gives the corresponding gauge height that would have existed at Bayou Sara, had the levees held. Continuing this process down stream between successive stations gives a table of theoretical high-water gauges, which, with levees holding, would have existed on May 16. A typical gauge relation curve is shown on Fig. 35, and a tabulation of theoretical gauge heights of May 16 is given in Table 1.

Fig. 36 is a profile showing the actual water surfaces of April 27 and May 16, the theoretical surface of May 16, and the approximate established grade line of the levees, all reduced to mean Gulf level. All gauge heights, etc., are as recorded by the Mississippi River Commission. The cross-hatched area on the profile is the difference between the actual and the theoretical water surfaces of May 16, and measures the effect of the Poydras Crevasse.

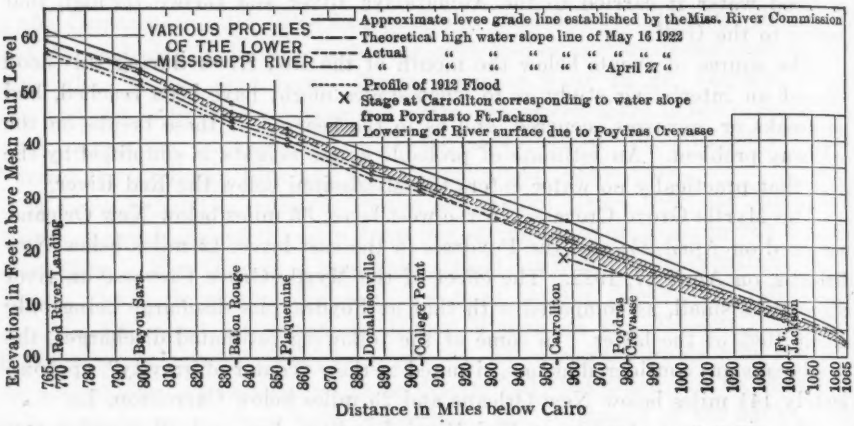
VARIOUS PROFILES OF THE LOWER MISSISSIPPI RIVER
Approximate levee grade line established by the Miss. River Commission
Theoretical high water slope line of May 16 1922
Actual " " " " " " " " "
" " " " " " April 27 "
Profile of 1912 Flood
Stage at Carrollton corresponding to water slope from Poydras to Ft. Jackson
Lowering of River surface due to Poydras Crevasse
Elevation in Feet above Mean Gulf Level
Distance in Miles below Cairo
Red River Landing
Bayou Sara
Baton Rouge
Plaquemine
Donaldsonville
College Point
Carrollton
Poydras Crevasse
Ft. Jackson

FIG. 35.

Table 2 shows estimated discharges of the river at the Carrollton gauging station for the actual and the theoretical conditions on May 16 and for a gauge reading corresponding to the profile of the river below the Poydras Crevasse. These estimates are based on the maximum discharge observed by the engineers of the Mississippi River Commission on April 28, and on the Hazen and Williams' formula $v = C' r^{0.63} S^{0.54}$, in which C' is assumed to be constant for the comparatively small variations in gauge heights. The theoretical slope of May 16 is taken as the slope from College Point to Carrollton, whereas other slopes noted in Table 2 are values interpolated between the slopes from College Point, La., to Carrollton and from Carrollton to Fort

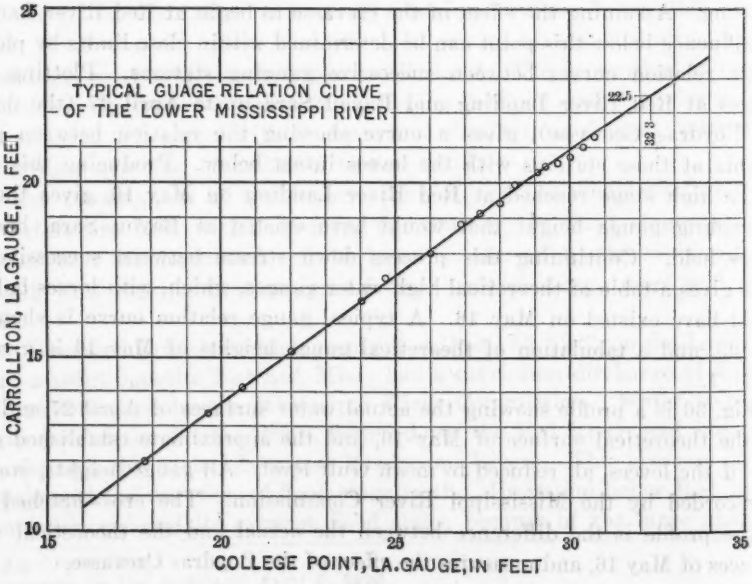
TYPICAL GUAGE RELATION CURVE OF THE LOWER MISSISSIPPI RIVER
CARROLLTON, LA. GAUGE, IN FEET
COLLEGE POINT, LA. GAUGE, IN FEET
22.5
32.3

FIG. 36.

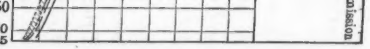

TABLE 1.—DATA ON FLOOD STAGE OF THE MISSISSIPPI RIVER BELOW THE RED RIVER.*

Stations.	Previous High-Water Record.		Distance below Cairo, in miles.	Distance between stations, in miles.	Elevation of zero of gauge referred to mean Gulf level.	1922 Gauge Heights, in Feet.			Established levee grade referred to mean Gulf level.	High-Water Slopes.		
	Year.	Gauge, in feet.				April 27.	May 16, actual.	May 16, theoretical.		April 27.	May 16, actual.	May 16, theoretical.
Red River Landing, La.	1912	53.20	765.3		3.57	53.8	55.3	55.3	61.1			
				34.7						0.160	0.163	0.160
Bayou Sara, La.....	1912	47.37	800.0		3.83	48.0	49.4	49.5	....			
				33.5						0.228	0.249	0.226
Baton Rouge, La.....	1912	43.82	833.5		−0.42	44.6	45.3	46.2	47.7			
				20.5						0.171	0.166	0.171
Plaquemine, La	1912	39.38	854.0		0.28	40.4	41.2	42.0	....			
				32.2						0.190	0.209	0.193
Donaldsonville, La.....	1912	35.10	886.2		−1.25	35.8	36.0	37.3	....			
				17.8						0.189	0.211	0.194
College Point, La.....	1912	30.18	904.0		0.29	30.9	30.7	32.3	....			
				53.0						0.189	0.212	0.193
Carrollton, La.....	1912	21.05	957.0		−0.13	21.3	19.9	22.5	25.1			
				8.2								
Algiers, La.....	1912	20.80	965.2		.....	21.5	19.7	22.5	....	0.164	from Carrollton to Fort Jackson.	
				74.0								
Fort Jackson, La.....	1916	8.80	1 039.2		−1.68	9.5	8.7	9.8	9.3			

* Gauge readings conform to the records of the Mississippi River Commission.

TABLE 2.—DISCHARGES OF THE MISSISSIPPI RIVER AT CARROLLTON, LA.

Date.	Gauge, in feet.	Sectional area, in square feet.	Slope, in feet per mile.	Hydraulic radius.	Velocity, in feet per second.	Discharge, in cubic feet per second.	Remarks.
April 28, 1922	21.1	195 450*	0.175	74.8	6.94	1 358 311	Observed by the Mississippi River Commission.
May 16, 1922.....	(19.9 Actual)	191 940	0.212	73.5	7.61	1 460 700	Estimated by writer.
May 16, 1922.....	(22.5 Theoret.)	199 400	0.185	76.0	7.22	1 440 000	" " "
May 16, 1922.....	17.95†	186 300	0.149	71.8	6.20	1 155 000	" " "

* This area estimated from discharge observed by the Mississippi River Commission, May 8, 1912, when the gauge read 20.4 ft. and the area measured 193 373 sq. ft.

† This gauge is estimated by producing the lower profile of May 16, 1922, from the Poydras Crevasse to Fort Jackson, La., back to Carrollton. The water surface of Poydras was doubtless lower than shown. This would give a lower gauge at Carrollton, and would increase the estimate of the discharge of the crevasse.

Jackson, La. It is to be noted that the discharge estimated from the theoretical conditions of May 16 is slightly less than that estimated from the actual conditions, which indicates that the theoretical gauge heights determined from gauge relation curves are conservative values.

The discharge of the Poydras Crevasse (here taken as Poydras and Myrtle Grove combined) by a process of elimination is found to be approximately 300 000 sec-ft. This particular estimate is a rough approximation, and is only about two-thirds of the discharge as estimated by the Mississippi River Commission.

An examination of Fig. 36 shows the theoretical water surface of May 16 to be approximately parallel to the levee grade line established by the Mississippi River Commission and from 2 to 2.5 ft. below it, except near the mouth of the river where there is a freeboard of only about 1 ft. As the levees in many places have not yet been completed to established grade and cross-section, and as the flood stage averaged probably 12 ft. higher than adjoining land, it is evident that a serious situation was relieved by the Poydras Crevasse. A great deal of topping of levees would have been required to prevent overflow, had not this break occurred. At several places, hundreds of men, with the necessary teams and grading equipment, were employed day and night for several days to make the levees safe.

The property values in the Atchafalaya and Pontchartrain Basins (including New Orleans) which are dependent on the levee system for protection from devastating floods, are so great that they would make the construction of spillways or safety valves to provide a greater degree of protection at least a debatable question, particularly until the levees below the mouth of the Red River have been completed to standard grade and cross-section and properly protected by revetments. For such an auxiliary system of flood control, there is a popular and growing demand among the residents of the localities mentioned.

The Ohio Basin was the principal source of the 1922 flood, and there was no record rainfall over the entire drainage area of the Mississippi; consequently, rainfall coincidences that will produce greater floods may reasonably be expected at long intervals. This recent experience even points to the possibility of increasing the heights of established levee grades, but the use of spillways should obviate such a necessity. Raising the levees would involve a great volume of earthwork, because the adopted levee cross-section would doubtless be maintained. The object to be attained is the enlargement of the cross-section of the river by deepening the channel, and not by again increasing the height of the levees as the greater their height, the greater is the destruction wrought by a crevasse.

The volume of the 1922 flood above the mouth of the Red River was approximately 2 000 000 sec-ft., whereas below this point it was about 1 450 000 sec-ft., the difference of 550 000 sec-ft. being the quantity that found its outlet through the Atchafalaya River. The cross-section and the slope of the river are greater from Cairo to the mouth of the Red River than below that point, and, consequently, the lower reaches cannot accommodate the flood flow

of the upper portion. For this reason, the Chief of Engineers, U. S. Army, in a recent report on the permanent separation of the Red and Atchafalaya Rivers from the Mississippi, deems the project inadvisable at this time, because of the interests threatened by the proposed work, including the City of New Orleans, the necessary enlargement of existing levees, etc.

The theory of flood prevention in the Lower Mississippi is that of forcing the river to deepen its channel and adjust its cross-section to accommodate the increasing volume by confining it within levees, thus increasing its velocity and its scouring capacity. However, practically every great flood in this part of the river has been accompanied by one or more crevasses through which more of the total flood flow was discharged for a longer period than that required for the relief of whatever temporary crisis the flood may have created. In view of this condition, it seems to be logical that spillways—or safety valves—properly designed, located, and operated, could be made to assist in enlarging the cross-section of the river instead of diminishing it, which appears to be the generally accepted opinion of the effect of spillways. Such a spillway system is not to be compared with the ideal condition of an extreme flood held between levees and discharged to the Gulf, but rather with the condition which has existed in past floods, as noted previously, and may reasonably be expected to exist in future floods.

The enlargement of the cross-section of the river must necessarily be a slow and gradual process, depending on the frequency and magnitude of floods, the proportion of the flood flow held between levees, and the nature of the bed to be scoured. Extended investigations of the Commission have established the fact that there is a well-defined tendency toward a cross-section of greater capacity, including a lowering of the bed of the river. This tendency toward enlargement has occurred during previous floods when a large part of the energy of the river has been dissipated through crevasses. The spillway theory would conserve a greater proportion of the energy by retaining a greater discharge between levees.

Assume a flood flow of 1 500 000 sec-ft. passing Red River Landing, with a crevasse discharging 400 000 sec-ft. at Plaquemine, La., approximately 90 miles below, as compared with the same flood flow at Red River Landing with 200 000 sec-ft. passing over a spillway into Lake Pontchartrain, 160 miles below. It is evident that the latter condition will have a decidedly more beneficial effect on the cross-section of the river below Plaquemine than the former.

In case of the crevasse, the levee is rebuilt when the flood recedes, and the silt deposited just below the break is scoured away when the velocity of the succeeding flood exceeds that at which the silt was deposited; whereas, with the spillway, the gates could be closed after the crest of the flood had passed, thus increasing somewhat the discharge and velocity below the spillway and leaving the river channel in better condition than before. Such spillways should not be permanent outlets, and should never be opened during moderate floods. They should serve as safety valves only in case of extreme floods, and should then hold within the levees a discharge as great as the levee system could safely carry. Such spillways are in no way comparable with Lower Old

River, which connects the Mississippi to the Red and Atchafalaya Rivers. In this case, there are reversals of flow, a condition ideal for the deposition of silt.

A spillway in the vicinity of La Place, La., discharging through a short canal into Lake Pontchartrain could be used in extreme floods to increase the velocity materially below the Red River. When this section of the Mississippi had been sufficiently enlarged to accommodate maximum floods safely, a similar spillway in the vicinity of the Poydras Crevasse discharging into Lake Borgne could be made to assist in enlarging the river down to this point, after which another spillway or spillways, farther down stream, could assist in deepening the channel to the Gulf. The spillways would then have served their purpose, and would seldom, if ever, be used again. The channel enlargement might be carried out to such an extent as to reduce materially the overflow down the Atchafalaya River and, perhaps, eventually, insure the advisability of separating the Red and Atchafalaya Rivers from the Mississippi permanently, which separation would greatly increase the value of agricultural lands in the Atchafalaya Basin by minimizing their likelihood of being flooded.

The location of the Poydras Crevasse was such as to make the discharge and the velocity of the river at New Orleans greater than ever before, and it doubtless had a beneficial effect on the cross-section up stream as far as Red River Landing.

Detailed investigations might prove the feasibility of converting the Poydras Crevasse into a spillway through which the discharge could be regulated, and that the construction of a spillway at or near the site of the old Bonnet Carre Crevasse (La Place) might not be necessary. Revetment work, which is essential for the protection of banks and levees from scour due to the increased velocities, should proceed with the spillway program, and levees, to the grade and cross-section established by the Commission, should be completed at the earliest possible date.

A consideration of the silt problem shows the advisability of discharging as great a part of the flood flow as possible through the various mouths of the river into the Gulf. In its present direction, the river has extended its delta to a point in the Gulf where the bottom has a steep slope to deep water. As a result, sediment carried to the Gulf by the main river reaches deep water, and the future extension of the delta here will be practically negligible. However, the silt discharged through spillways should not interfere seriously with their successful operation. They would discharge the relatively clear surface water, and would be in operation perhaps only once in five or ten years. After a spillway had acted as a safety valve in a number of extreme floods, it would have served its purpose, as noted previously, and another spillway farther down stream would be constructed.

Samples taken in April, 1922, near the water surface, at a point about 35 miles above New Orleans by river, showed an average turbidity of 830 parts per million, with a maximum of 1 000 and a minimum of 750. Corresponding values for May were, 710, 750, and 600, the clearer water during May probably being due to the return of back water from the Weecama Crevasse.

Assuming that a spillway discharges 250 000 sec-ft. for a period of 30 days, and that the water has a turbidity of 1 250 parts per million, the quantity of sediment in suspension would be about 19 000 000 cu. yd. Such a quantity of sediment would necessarily have considerable effect in silting shallow bodies of brackish water. When deposited in Lake Pontchartrain, or Lake Borgne, some of this sediment might be transferred by hydraulic dredges to near-by swamp lands, thus converting them into valuable property.

C. McD. Townsend,* M. Am. Soc. C. E.—The use of spillways and outlets as a means of reducing flood heights has probably been discussed in New Orleans after every flood that has occurred in the Mississippi River during the past 75 years. Humphreys and Abbot give an exhaustive investigation of the subject in their report on the Mississippi River, published in 1861, and quote from a report by A. D. Woodbridge, State Engineer, submitted to the Senate of the State of Louisiana in 1852. Their conclusions, selected as a text for the speaker's remarks, are as follows:

"Outlets are then of great utility, so far as the river is concerned, but they are virtually impracticable from the difficulty of disposing of the water. * * * An outlet between the Arkansas and Red Rivers possibly advantageous to a limited district. * * * No artificial outlets practicable on the right bank below Red River. * * * On the left bank three localities have been suggested, * * * at Old Bayou Manchac, * * * at Bonnet Carré bend, * * * and at Lake Borgne."

After discussing the various theories which had been advocated in reference to outlets at these localities, they close the chapter on outlets with the statement:

"Enough has been said to demonstrate, with all the certainty of which the subject is capable, the disastrous consequences that must follow the resort to this means of protection."

In the days of Humphreys and Abbot, the science of river hydraulics was in its infancy, and there was some justification in discussing the question whether or not the confinement of a river's discharge between levees would increase flood heights. During the last 40 years of levee construction, however, the Mississippi River has solved the problem so conclusively that its discussion before this Society at present is unprofitable.

The reverse proposition is also self-evident. If the levee line was destroyed, flood heights would be diminished, and if water was permitted to escape through crevasses, outlets, or spillways, the lowering of flood heights would bear some relation to the quantity extracted from the channel.

Nor is it profitable to discuss the influence of levees on the low-water navigation of the Mississippi in the vicinity of New Orleans. Good navigation for sea-going vessels existed from New Orleans to the Head of the Passes in the days of Humphreys and Abbot, and also exists to-day.

The speaker agrees with Humphreys and Abbot that the sole problem of the spillway is whether it is cheaper to confine the flood waters of the river between levees, or to afford the necessary protection against the effects produced by the water which is permitted to escape.

* Col., U. S. A. (*Retired*), Brooklyn, N. Y.

A waste weir at the head of every basin in the Mississippi Valley would reduce flood heights along its front, but also would flood it. Therefore, a second levee line would be required to confine the overflow; and the combined cost of the two levee systems would exceed that of one line of the necessary height to restrain the flood to the river channel in every basin above the mouth of Red River.

The same reasoning, also, would apply to the Atchafalaya spillway, if that river was confined between levees from its source to its mouth; but large areas in the Lower Tensas and Atchafalaya Basins are allowed to be overflowed, forming immense reservoirs, which reduce flood heights. Whenever the problem of reclaiming these lands arises, the closure of the mouth of Old River resolves itself into a question whether the planters along the Lower Mississippi River are to submit to increased taxation for a higher levee line, or whether the owners of the property to be benefited will pay for the levee line which will protect it.

Both Bayou Plaquemine and Bayou La Fourche, on the right bank of the river, are too small to afford much relief, if they were to be re-opened and converted into spillways.

In one of the speaker's numerous papers on, "How to Control Mississippi Floods," written during the past 30 years, he expressed the opinion that a spillway could be constructed on the left bank of the river emptying into Lake Pontchartrain which would fill instead of scour. He had in mind, a spillway in the vicinity of Bayou Manchac. The flow in such a spillway would have a gentle slope, but, if permitted to discharge 250 000 sec-ft., not only would it be necessary to restrain the discharge by a levee across the basin to Lake Maurepas, but to protect also the shores of Lakes Maurepas and Pontchartrain from overflow. He is still of the opinion that, if an additional spillway to the Atchafalaya outlet is required, this is the least dangerous location for it, and the one that will produce the maximum lowering of flood heights on the lower river. By giving it ample width, scour can be reduced to a minimum.

In discussing outlets near New Orleans, Humphreys and Abbot invite attention to the treacherous soil, as revealed by borings made by them at this locality. Borings submitted by the Committee of 100 on a project for a spillway at Lake Borgne confirm their assertions. These borings which were made in 1874, indicate that the site of the weir is overlaid by a layer of mud 5 to 15 ft. deep. Beneath the mud are alternate layers of sand and clay to a depth of 60 ft. below mean Gulf level, and extending below these for a distance of about 25 ft. is a layer of quicksand.

In constructing the weir it is not proposed to remove this material, but to support the structure on a series of piles extending to a depth of 45 ft. below the surface, with walls of sheet-piling driven to a depth of 24 ft., to cut off the flow of water under it. The river bank is protected by a mattress of the type adopted by the Mississippi River Commission. Protection on the land side is afforded by a series of cribs, 60 ft. wide, filled with stone, and by an apron 200 ft. wide, which consists of clay gravel 4 in. thick (rolled by a 10-ton roller) and overlaid by 12 by 12-in. pre-cast blocks, 6 in. thick, threaded on ½-in.

galvanized-iron cables. A timber bridge, 700 ft. from the crest of the weir, is planned for railroad and highway traffic.

After a river has adjusted its cross-section to its discharge, as is the case in the beds of most alluvial streams, such a structure affords reasonable protection against injurious percolation under it. The Laguna Dam, built by the U. S. Reclamation Service, is an example of an overflow weir founded on alluvium, which resists floods successfully; and numerous weirs of similar design have been constructed in India.

When the overflow has to create a new channel, conditions are entirely different, and provision must be made for scour to great depths.

If such a spillway is built, a sheet of water would flow over the layer of surface mud on a slope of 6 on 3 000 at the beginning of an overflow, and, at the site of the bridge, would encounter obstructions caused by its piers. The obstructed flow would create a scour in the bridge openings, and the channels thus formed would enlarge rapidly as the discharge increased. They would also cave back to the curtain of the weir, and the outer edge of the apron would fall into the holes which were scoured. The 4-in. layer of clay gravel rolled by a 10-ton roller would tend to prevent the flow of the layer of mud under the apron, and banks with steep slopes would be created at its edge, revetted by the concrete blocks of which it is composed.

This revetment would be exposed to the static pressure of the entrapped mud and of such layers of clay and sand as the scour had penetrated. Such layers attain stable equilibrium under water when their slopes are about 1 on 2 for clay, 1 on 4 for sand, and less than 1 on 10 for mud. The curtain, therefore, must act as a retaining wall, for which purpose it is not adapted. When this heterogeneous mass starts to slide, it will carry a part of the curtain with it, and there will be a break in its surface.

When such a break takes place, chaos will result. The scouring action of the overflow will be intensified above and below the sliding mass, and the underlying layer of quicksand will be penetrated. Quicksand saturated with water will flow nearly as readily as water itself, and the whole superincumbent mass of sand, clay, piles, and concrete will begin to settle and move toward the Gulf.

The floods of the Mississippi River have taught lessons which should be heeded. The Poydras Crevasse demonstrates the facility with which Louisiana alluvium is scoured to depths of 80 to 100 ft. by the overflow of the river banks. The failure of a revetment to act as a retaining wall cost the City of Greenville a strip of land about 900 ft. wide and nearly 1 mile long during the flood of 1892. Revetments at Plaquemine and Panther Forest have failed from the same cause. The settlement which occurred at Helena, Ark., during the flood of 1916 illustrates the danger of allowing layers of quicksand to escape, even at great depths, and the difficulties experienced in constructing the lock of the new channel at New Orleans emphasize the same lesson.

As another illustration, assume that the Culebra Cut of the Panama Canal had been revetted with clay gravel, 4 in. thick, rolled by a 10-ton roller, and overlaid by 12 by 12-in. pre-cast concrete blocks, 6 in. thick, threaded on ½-in.

galvanized-iron cables. How much resistance would there have been to the slides which occurred there?

Ordinary prudence dictates that, if a reasonably safe spillway is to be constructed at this locality, either the surface mud must be protected from erosion by a substantial covering extending from the weir to Lake Borgne, or the material which is likely to flow must be removed from the site of the weir to the depth to which scour will occur, and rock substituted for it. Either plan makes the cost of the spillway prohibitive and largely in excess of that of the enlargement of the levee line which it is proposed to replace.

Investigations, made at the suggestion of the speaker after the flood of 1912, disclosed serious objections to a spillway as a means of reducing flood heights at every locality that had been suggested. A confined waterway induces scour, whereas an unrestrained overflow produces a fill. The spillway at Lake Borgne is subject to both objections.

Although it is self-evident that a spillway will reduce flood heights, it by no means follows that the reduction will be as great as the Committee of 100 estimates. An analysis of the flood of 1922 indicates the errors which it has made in its computations. Two flood waves were propagated down the river, one culminating at Cairo on March 26, with a gauge height of 53.6 ft., and the second on April 25, with a gauge height at 53.5 ft. At Helena, there is no material change in the form of the hydrograph, the Helena gauge reading 52.3 ft. on April 3 and 53.1 ft. on May 3. On April 15, the crest of a flood in the Arkansas River passed Little Rock, and its discharge changed materially the form of the hydrographs from the mouth of White River to Vicksburg, producing a maximum flood height of 56.8 ft. at the mouth of White River from April 18 to April 27, whereas the rise from Helena of May 3 could only raise the White River gauge to 56.6 ft. At Vicksburg, the maximum stage was attained on April 27, and the gauge remained stationary only 3 days, due to the crevasse at Weecama. It then fell 0.2 ft. and remained stationary until May 8. The normal maximum discharge, however, had passed Vicksburg prior to the crevasse, and arrived at Red River Landing also on April 27 producing a stage of 53.8 ft. The maximum discharge usually precedes the maximum gauge reading by 2 or 3 days, due to the reservoir capacity of the river. If the crevasse at Weecama had not occurred, a maximum gauge reading not exceeding 54.1 ft. would have been recorded at Red River Landing on May 1, and would have produced a height on the Carrollton gauge not exceeding 21.5 ft. on May 2. Its hydrograph would have conformed to those at the mouth of White River and at Vicksburg, and it would have remained at its maximum for at least one week.

The gauge at Barbara Landing, on the Atchafalaya River, discloses what occurred after April 27. On that date, its reading was 52.7 ft., but while the gauge at Red River Landing then began to fall, that at Barbara Landing continued to rise, and by May 3 had attained a greater elevation above Gulf level than the mouth of Red River. During the remainder of the flood, the gauge at Red River Landing rose and fell with that at Barbara Landing. In other words, the Weecama Crevasse converted the mouth of Old River from an outlet on April 27 into an inlet on May 3.

Any attempt to predict flood heights from gauge relations after such a radical change in the regimen of the river is impracticable. The computations of the Committee of 100, therefore, are not based on the flood heights which would have existed if the levees had held, but on the assumption that the crevasse which occurred at Weecama had not been accompanied by one at Poydras, and are defective, even under such an assumption. They suggest, however, that the funds, estimated as necessary to construct the spillway, can be expended more profitably in strengthening the levees of the Tensas Basin and thus removing the cause of the imagined increase in flood heights.

One of the engineers of the Committee of 100, in defending its conclusions, has asserted that the closure of the Cypress Creek Gap in the Tensas District raised flood heights 7.4 ft. at Arkansas City during the flood of 1922, and bases his conclusions on a comparison of the gauge at this locality with that at Memphis.

The speaker has frequently called attention to the danger of attempting to deduce general laws from special cases, without a careful analysis of the existing conditions. This is illustrated forcibly in the present instance. If the gauge above Memphis at Fulton had been selected for the comparison, a difference of 7.8 ft. would have resulted, whereas, if the gauge below Memphis at Moons Landing had been chosen, the difference would have been 3.1 ft. A similar comparison of the Moons Landing gauge with that at Greenville, the next gauge below Arkansas City, would indicate that the closure of the Tensas Basin had raised flood heights 1.7 ft. A process of reasoning in which the conclusions are dependent on the skill exhibited by the investigator in the selection of his stations would not be worthy of further discussion, if it were not for the fact that such discussion reveals other errors made by the Committee of 100.

Gauge relations are affected, not only by the maximum discharge, but also by the rate of rise, the inflow from tributaries, and by a change in the river section. Table 3 shows the changes in flood heights which have occurred since 1882 at the gauge stations of the Mississippi River Commission, from Cairo to Vicksburg, during the floods of 1913, 1916, and 1922.

TABLE 3.

	1913	1916	1922
Cairo	2.8	1.3	1.7
Columbus	4.2	3.4	3.9
Cottonwood Point	4.8	2.0	1.0
Fulton	7.4	3.5	2.5
Memphis	11.4	8.25	7 35
Moons Landing	5.5	5.0	5.3
Helena	8.0	6.2	5.9
Sunflower Landing	9.6	10.0	9.3
Mouth of White River	6.9	8.1	8.2
Arkansas City	8.0	9.3	10.9
Greenville	9.0	9.0	10.5
Lake Providence	9.7	10.5	11.2
Vicksburg	3.5	5.1	6.1

An examination of Table 3 reveals the large increase in flood heights which has accompanied levee construction, but it is to be noted that the amount of the increase varies materially at the different stations. During the flood of 1913, it attains a maximum (11.4 ft.) at Memphis, and during the flood of 1922, 11.2 ft. at Lake Providence. There was also a lowering of the gauge relations along the St. Francis Basin at Cottonwood Point, Fulton, and Memphis, during the floods of 1916 and 1922, which attained a maximum of 4.9 ft. at Fulton in 1922. Along the Tensas Basin there is a corresponding successive increase in gauge relations at Arkansas City, Greenville, and Lake Providence, attaining a maximum of 2.9 ft. at Arkansas City, also in 1922. Along the White River Basin, there is a tendency toward higher readings during the flood of 1916.

Although Table 3 demonstrates that a powerful force raised flood heights along the St. Francis Basin in 1913, it also indicates that a similar force was lowering flood heights at Cottonwood Point, Fulton, and Memphis during those of 1916 and 1922. In 1916, the gap in the levee line of the Tensas Basin at Cypress Creek had not been closed, and, therefore, levee construction at this locality cannot account for the change in conditions of that year.

In a discussion submitted to the Society in 1896,* the speaker compared the Mississippi River to a water main and its hydraulic grade line, and suggested that the confinement of the river between levees through the St. Francis Basin would produce an effect similar to that of substituting a smaller pipe for that part of the water main. The only method of forcing the same quantity of water through the smaller pipe would be by increasing the pressure, and raising the hydraulic grade line, that is, by increasing flood heights.

If, however, this increased pressure gradually enlarged the river section, the effect would be similar to that which would be produced by replacing the pipe with one of a greater diameter. If the river section along the Tensas Basin did not enlarge to a similar extent, there would have been substituted for a water main of uniform size, a large pipe at the upper end of the water system connected with a smaller one below it, and the hydraulic grade line would be lowered at the upper end of the system and raised at the junction of the two sizes of pipe.

This illustration affords a rational explanation of existing conditions. From 1913 to 1922, the river above Helena has been discharging, during floods, about 300 000 sec-ft. more than below Arkansas City, and, therefore, has had an opportunity to enlarge its cross-section more rapidly along the St. Francis Basin than along the Tensas Basin. In 1916, the point of junction of the two sizes of pipe appears to have been near Sunflower Landing; in 1922, near Arkansas City.

In addition to the change in section, however, other forces have been acting. The maximum flood discharge at Cairo, the rate of rise, and the inflow from the White and Arkansas Rivers, have varied in the different years, and the closure of Cypress Creek increased flood heights along the Tensas Basin in 1922. A reduction in the maximum discharge will account for the lower reading at

* *Transactions*, Am. Soc. C. E., Vol. XXXV (1896), p. 336.

Cairo in 1922 than in 1913, the rate of rise, for a part of the change in gauge relations at Helena, and variations in the Arkansas River, for the changes in the form of the hydrographs below the mouth of White River. The discharge observations taken during the flood of 1922 give a maximum discharge at Helena of about 100 000 sec-ft. less than at Arkansas City.

In conclusion, attention is invited to the fact that, after an expenditure on the levee line of more than $49 000 000 by the United States Government and local authorities between the floods of 1912 and 1922, flood heights have been raised only 0.25 ft. at Carrollton, and have not yet attained by nearly 1 ft. the elevation that the Mississippi River Commission estimated would result from a confined flood like that of 1912. This is insignificant in comparison with the increase in flood heights at other localities, and suggests that the construction of the city levees to Commission grade will solve the problem. The Poydras Crevasse did not result from a weak levee, but from a caving bank, and indicates that bank protection is a more important adjunct to the levee system than spillways.

THEORETICAL FREQUENCY CURVES AND THEIR APPLICATION TO ENGINEERING PROBLEMS

Discussion*

By Messrs. Frederic H. Hapgood and Richard T. Dana.

Frederic H. Hapgood,† Jun. Am. Soc. C. E. (by letter).‡—The writer has been interested in this paper, as he has also studied Elderton's frequency curves to some extent, and he believes the author did remarkably well to reduce the application of one of those curves to such simple terms.

The writer, however, raises the question whether or not the single type selected and developed can always be used to represent rainfall and run-off data. In order to develop this point, a brief outline of Elderton's curves will be given. These curves consist of seven principal types, all derived from a common basis. From practical considerations and from consideration of the theory of probabilities, it was decided that all frequency curves can be developed from the equation;

$$\frac{1}{y} \cdot \frac{d\,y}{d\,x} = \frac{a + x}{b_0 + b_1\,x + b_2\,x^2}$$

The integration of this equation depends on the nature of the roots of the equation, $b_0 + b_1\,x + b_2\,x^2 = 0$, which, in turn, depends on the value of the expression, $\frac{{b_1}^2}{4\,b_0\,b_2}$.

For any frequency series, Elderton shows how these constants can be computed from the values of the average of the series and of the squares, cubes, and fourth powers of the deviations from the average. He calls these last four quantities μ_1, μ_2, μ_3, and μ_4, respectively. Then he lets,

$$\beta_1 = \frac{{\mu_3}^2}{{\mu_2}^3} \text{ and } \beta_2 = \frac{\mu_4}{{\mu_2}^2}$$

Finally,

$$\frac{{b_1}^2}{4\,b_0\,b_1} = K = \frac{\beta_1\,(\beta_2 + 3)^2}{4\,(4\,\beta_2 - 3\,\beta_1)\,(2\,\beta_2 - 3\,\beta_1 - 6)}$$

This last equation determines the type to which the series belongs and Fig. 12 and Table 8 show the principal types that were developed.

The test just mentioned was applied to the data given in Fig. 6§ of the author's paper. The necessary series were obtained by scaling off the values represented by the dots and circles on the diagram and by changing the scaled

* Discussion of the paper by H. Alden Foster, Assoc. M. Am. Soc. C. E., continued from August, 1923, *Proceedings*.

† Jamaica, N. Y.

‡ Received by the Secretary, July 25, 1923.

§ *Proceedings*, Am. Soc. C. E., May, 1923, p. 851.

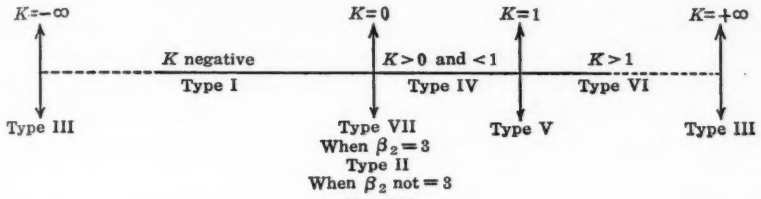

FIG. 12.

values slightly, so that their average was unity in each case. Then, the values of μ_2, μ_3, μ_4, β_1 and β_2, and, finally, the criterion, K, were computed for each series. In the case of the Croton River, K was found to be -0.13, corresponding to Type I, and in the case of the Hudson River, K was found to be $+0.15$, corresponding to Type IV. In neither case do these values show the series to belong to Type III, which is the type developed by the author.

TABLE 8.

Type.	Description of curve.	Equation of curve.	Mode.	Criterion.		
				K	β_1	β_2
I	Limited range in both directions (skew)...	$y = y_0\left(1+\frac{x}{a}\right)^{v a_1}\left(1-\frac{x}{a_2}\right)^{v a_2}$	Origin	<0	....	.....
II	Limited range in both directions (symmetrical).....	$y = y_0\left(1-\frac{x^2}{a^2}\right)^{m}$	Origin	$=0$	$=0$	not $=3$
III	Limited range in one direction (skew).....	$y = y_0\left(1+\frac{x}{a}\right)^{\delta a} e^{-\delta x}$	Origin	∞*	....	.....
IV	Unlimited range (skew)..	$y = y_0\left(1+\frac{x^2}{a^2}\right)^{-m} e^{-v\tan^{-1}\frac{x}{a}}$	$-\frac{v a}{2 m}$	>0 and <1	....	.....
V	Limited range in one direction (skew).....	$y = y_0 x^{-\rho} e^{\frac{-\delta}{x}}$	$\frac{\delta}{\rho}$	$=1$	....	.....
VI	Limited range in one direction (skew).....	$y = y_0\left(x-a\right)^{q_2} x^{-q_1}$	$\frac{a q_1}{q_1-q_2}$	>1 and $<\infty$	....	.....
VII†	Unlimited range (symmetrical).....	$y = y_0 e^{\frac{-x^2}{2}\rho^2}$	Origin	$=0$	$=0$	$=3$

* Elderton claims that it would probably be sufficiently accurate to use this type when K is arithmetically greater than 4.

† Normal law of error.

The object of work of this kind is to provide some basis for smoothing out and extending the data. The main body of the data may usually be fairly well represented by several different types. However, in the extension of the ends of the curves representing the data, the choice of type makes a difference. It may be argued that the series that are now available do not contain sufficient numbers of terms, that is, do not cover sufficiently long periods of time, to enable one to compute the constants accurately enough to determine the type. If that is the case, however, then the data warrant only a rough approximation, such as could be obtained by a simple plotting on some kind of probability paper and the drawing of a smooth curve through the points. On

the other hand, if any indication of type can be obtained from the series available, it should be shown by series longer than the average, such as the two records mentioned previously. They do not point to the type of curve used by the author and neither do they point to another single type. It would seem rather that data for each stream might be represented by a different type of frequency curve.

It seems to the writer, therefore, that in the application of Elderton's curves more work must be done in determining just what type of curve can be used to represent given kinds of data before any great degree of refinement can be expected from the analysis.

RICHARD T. DANA,* M. AM. SOC. C. E. (by letter).†—This paper is of particular value, not only to the Engineering Profession, but to the general world of science and industry, because it has helped so materially to make the theory of probability available to the person of limited mathematical experience. This theory, for which no one seems to have found a sufficiently comprehensive name, touches all activities, and the proper application of it to the various problems in which it is relevant must necessarily make for economy in an immense field. The difficulty in its application, heretofore, has been that most of those who have need of it, have not the necessary command of mathematics, and the number of people who have that knowledge seems to be increasing much more slowly than those who need to use the theory. The only escape from this predicament is the development of methods that can be applied by the non-mathematical layman.

Of such methods, probably the most generally effective have been the development of nomographic charts after the theory of M. d'Ocagne, of Paris, France, and the invention of probability paper by Allen Hazen, M. Am. Soc. C. E. Probability paper which, in its present form, is plotted for symmetrical curves only, might perhaps be modified so as to enable the skew curves to be plotted thereon as straight lines, thus greatly increasing its present usefulness. Mr. Foster is to be congratulated on the clearness of his method of presentation, no less than on the enterprise and energy involved in the production of so excellent a mathematical work. His paper is certain to prove to be of great value.

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* Cons. Engr., New York, N. Y.

† Received by the Secretary, August 4, 1923.

THE DISINTEGRATION OF CEMENT IN SEA WATER

Discussion*

By Messrs. Nathan C. Johnson, W. M. Black, Alfred D. Flinn, Benjamin A. Howes, Thomas H. Wiggin, Robert Ridgway, Richard H. Gaines, J. R. Slattery, Kenneth Allen, John Charles Riedel, Charles Rufus Harte, Chandler Davis, and Alfred H. White.

Nathan C. Johnson,† Assoc. M. Am. Soc. C. E. (by letter).‡—The patient search of existing literature, embodied in this paper, must command the admiration of all. Based on this search, issues are courageously raised and conclusions stated in a manner that demands an effective response, whether or not present convictions are altered and whether or not agreement with the authors' conclusions is had by the many men of many minds to whom the paper is addressed.

Not the least important of the issues raised, is that all American cements now available for whatever purpose, are made to one specification, particularly to a specification of which no man knows the technical or commercial worth. For lack of knowledge, this specification is standard, and its mere mention in a construction specification, is commercially deemed all-sufficient to protect any structure, no matter how made and situated, either in water or on land, against any possibility of trouble. Would that such magic were possible!

Another issue, indirectly brought forward, is: "What constitutes a failure in concrete"? On the majority answer to that question in the next few years, depends the degree of progress that may be hoped for, both in cement manufacture and in the making of concrete. There are without question disintegrations of greater or less severity in concrete and in great numbers of structures, but the importance of these disintegrations in structures that as yet continue to fulfill their functions, is a matter of disagreement.

This inability of minds to meet on so fundamental a question, added to human inertia, makes progress difficult, as there is no objective and few laurels for him who searches one out. Nevertheless, it is the writer's belief, not only that cement should be and may be improved, but also that cement for use in a definite severity of service should and must possess qualities fitting it to withstand the rigors of that service, rather than being capable

* This discussion (of the paper by William G. Atwood and A. A. Johnson, Members, Am. Soc. C. E., published in August, 1923, *Proceedings* and presented at the meeting of June 13, 1923), is printed in *Proceedings*, in order that the views expressed may be brought before all members for further discussion.

† Cons. Engr., New York, N. Y.

‡ Received by the Secretary, June 9, 1923.

only of meeting in uncertain test a specification of indeterminate values, based largely on commercial expediency. It is further the writer's belief that hand in hand with this must come relief from purely competitive price bidding and awards on important concrete work, through which, in present practice, a haste, a carelessness, and a quality of workmanship is caused to be embodied in a product that cannot hope to endure beyond a limited span in any exposure possessing more than medium severity. Such changes would make visible and manifest an objective that now is too nebulous to define specifically.

The paper at least, will bring about a crystallizing of diverse opinions, which, in turn, will cause real progress in the great cement and concrete industries. It is to be questioned whether any industries of comparable magnitude have spent or are spending so little in a dispassionate and fundamental research as to the nature and real value of their product.

W. M. Black,* M. Am. Soc. C. E. (by letter).†—During the period 1886-87, repairs were being made under the writer's direction to Fort Marion, St. Augustine, Fla. At that time there was only one brand of Portland cement manufactured in the United States. Norton's Rosendale cement, a natural cement, was in extensive use for fortifications and other heavy masonry construction. The Portland cement in use came from England and Belgium. Mainly in the work on the Fort there was used an English Portland cement which for fineness, time of setting, and tensile strength, fulfilled the requirements of the specifications then the standard. With this cement the concrete arch and other repairs were made on Fort Marion, using bank sand with coquina (finely broken shell) as the coarse aggregate. At the same time the writer made several blocks of concrete of these materials, about 1 ft. cube. These blocks were placed on the beach below the low-water level. A year or two later the writer took up the blocks and found that the cement had been acted on by the sea and had been transformed into a material resembling lime paste, the greater part of which had disappeared. The blocks had become porous, resembling a sponge in structure, and readily crumbled when crushed in the hand. The concrete which had been constructed in the air from the same materials and in the same proportions had hardened and was of excellent quality. The arch is still standing uninjured and is supporting its load. This action of sea water on concrete was reported at the Annual Convention of the Society in 1892. A little later, the writer had occasion to inspect the sea wall which had been built of Norton Rosendale cement at Fort Taylor, Key West, Fla., about thirty years earlier. The face of the wall seemed to be perfectly strong and hard; on the top where the sea water collected in small pools after heavy wave action, the concrete was so soft that it could be readily dug out with a pocket knife.

In 1886, some groins were built for the protection of the North Beach at St. Augustine, Fla., against erosion by the sea. These groins were capped with heavy blocks of concrete which were built in place at low water and were submerged at high water and during storms. To obtain more information on the

* Maj.-Gen., U. S. A. (*Retired*); Cons. Engr., Washington, D. C.

† Received by the Secretary, June 13, 1923.

action of sea water, a number of brands of cement were used, among which were the Anchor, Sphinx, and Dyckerhoff Portland cements and Norton and Fisher's U. S. G. Rosendale cement and also the hydraulic lime of Teil. Proportions for Portland were 1 cement, 4 beach sand and 6½ coquina gravel; for the Norton Rosendale 1 cement, 1 beach sand, 2⅔ coquina gravel; for Fisher Rosendale 1 cement, 2 beach sand and 4 coquina gravel; and for the hydraulic lime of Teil, 1 cement, 2 beach sand and 4 coquina gravel. The beach sand was almost entirely silicious. The grains were rounded and so fine as to pass almost the same test for fineness as the cement itself. Precautions were taken to protect the fresh concrete for at least two days and it was found that after the concrete had attained a tensile strength of 30 lb. per sq. in. the protecting box could be removed without damage or injury to the concrete by wave action. An American Portland cement was tried, using the same proportions as for the other brands of Portland cement. This, however, flaked badly after it was set, under the action of the salt water. By reducing the proportions of sand and coquina by one-half, the concrete made with this American Portland cement also withstood the action of the salt water. The groins fulfilled their function excellently and no disintegration was noticed after a number of years.

From 1899 to 1901, the writer made a number of concrete constructions in sea water at Havana, Cuba, all of which were in perfect condition in 1909 and showed no signs of disintegration. In these works a brand of cement was used which was known to withstand the action of the sea and the concrete was made rich and as little porous as practicable. Later, the writer used concrete in capping dikes and training walls in the Upper Hudson River in the vicinity of Albany and again used a rich concrete with American Portland cement of a brand which was known to stand well under water, taking care to protect the concrete against wave and current action until it had set strongly. The only failures found were at one or two places where the concrete had not been protected adequately until it had set and some experimental work placed with the cement gun, which flaked badly under frost action.

As far as the writer has been able to observe, where chemical action on the cement does not take place, the effects of frost and of sea water on concrete are similar. In sea water, in the absence of accurate knowledge as to chemical action, the writer has made it his practice to use a rich, non-porous mixture, with a cement which experience has shown will not be acted on by sea water.

ALFRED D. FLINN,* M. AM. SOC. C. E.—The authors are to be commended for having taken early the important step of finding out what others have done, and presenting it as a prelude to reports of their own studies.

Thirty years' experience and observation with concrete in a variety of uses, have given the speaker a continuing interest in the subject. Several years ago, at a few places on the Catskill Aqueduct, there were certain troubles with concrete, which led to careful search for the causes. Those causes proved to be various. Intimate studies were made of the aggregates and of the cements. Among those who helped were Benjamin A. Howes and

* Secy., United Eng. Soc., and Director, Eng. Foundation, New York, N. Y.

R. J. Wig, Members, Am. Soc. C. E., Nathan C. Johnson, Assoc. M. Am. Soc. C. E., and Professor R. J. Colony. In addition to experience with cements in sea water and in soils, assistance may be obtained from experiences like those on the Catskill Aqueduct. Fundamental studies of cement cannot but contribute to a fuller understanding of concrete for whatever purpose it may be used.

There should be different standard specifications for cement for the widely different kinds of concrete work. Standard specifications of the type which has been used commonly yield cements which are not alike. It may be disadvantageous to complicate standard specifications with details which apply only to special cases. May not such studies as those contemplated by the Committee on Marine Piling Investigations lead to authoritative statements of qualities which should be provided in cements for particular kinds of work? Then, the engineer having special requirements will be able to stipulate in addenda to standard specifications the qualities which he must have. When insisting on special qualities which must be produced by special effort, both the engineer and the owner should see the fairness of paying accordingly. It may be that the making of cement to special specification may become a sufficiently large business to justify one or more mills devoting their attention thereto.

Benjamin A. Howes,* M. Am. Soc. C. E.—The history of an art carries with it much counsel and assistance to its later practitioners. The profession is indebted to the authors for this clear and complete review of the problems of hydraulic binders. It shows that the present-day problems of disintegration are not new and are not yet solved.

The use of Portland cement has now had wide scientific study and engineers are in a fair way to use these results in practice. Such studies, however, are now nearly at a dead end because the manufacture of cement and its constitution has not yet been brought under scientific control. It appears to be widely held that Portland cement is a standard product and that the only study warranted is that of the methods and materials attending its use. Bitter and costly experience, however, has shown quite the contrary; that the products of different mills, and even different runs of the same mill, do not always behave the same under like conditions.

The speaker has found typical sea-water disintegration proceeding in large concrete works where only fresh water was present. In some instances, the work was situated in the mountains remote even from sea air. In such cases, as well as in sea water, there is often found older work, done with less technical skill, enduring the same exposure with complete permanence. This indicates some peculiarities of modern Portland cement that demand attention. The typical disintegration which is so alarming, proceeds as follows:

The structure for two years or more after completion stands well and passes skilled inspection as good concrete. Specimens tested for crushing strength show proper results. Slowly, hair or map cracks appear, which usually show a black discoloration. Gradually, hard plates, from a few inches to

* Cons. Engr., New York City.

several feet in area, split off from the surface. Below these plates is found a zone of weakness several inches deep, in which the cement may be absent or the aggregate may be surrounded by a pasty material resembling hydrated lime. Below this zone of weakness, the concrete is hard and tight, but this hard concrete under the same exposure disintegrates in the same manner. Such disintegration takes place in sea water, fresh water, and when only exposed to rains. It is, of course, more rapid where there is abrasion or the more active dissolving action of sea water or moving water.

It was not until the work done about ten years ago at the Geo-physical Laboratory of the Carnegie Institution that a real basic explanation of the constitution of Portland cement was furnished. These results were later confirmed by the U. S. Bureau of Standards. From this, it is quite thoroughly shown that Portland cement is a mixture of three distinct hydraulic binders which act, as far as they are ground sufficiently fine, at different stages of the setting and hardening. There are also some commercial impurities, such as iron oxide, magnesia, etc., that do not affect the functioning of the cement, and some lime sulphate, or gypsum, that retards its setting. These three ingredients are, in the order of their setting or hardening action, tri-calcium-aluminate, tri-calcium-silicate, and di-calcium-silicate.

Errors of manufacture tend first to produce a deficiency of tri-calcium-silicate. This deficiency cannot be determined by chemical analysis, because there is no chemical procedure that will separate the three ingredients. Just to the degree that such deficiency is present, the cement as it hydrates sets free an excess of hydrated lime. To the same degree the resulting mortar or concrete becomes a lime mortar or concrete with a similar drop in permanence under hydraulic exposure.

More definite working knowledge of this phenomenon is necessary before engineers can proceed intelligently to determine whether silicate (puzzuolanic) admixtures are desirable for sea-water exposures with properly made Portland cement. If it is found to be desirable to make such additions, it will probably be found wiser to make them under rigid technical control at the mill during manufacture. Certainly, the permanence of Portland cement and the concrete made with it calls for a more scientific knowledge of the constitution of the cement and its hydration, in conjunction with its behavior in ancient and modern works.

In the course of some solution experiments, many specimens of good concrete and concrete that had failed were immersed separately in fresh water (New York City water) in glass beakers. With specimens of sound concrete taken from the zone below disintegrating surfaces, a film slowly formed at the surface over a period of months. As the film attained appreciable thickness, it sank to the bottom and fresh film formed and considerable sediment accumulated in the form of plates or scales at the bottom of the beakers. Chemical analysis was not available at the time to determine the nature of this sediment which had dissolved from the concrete. Specimens from concrete that had shown no evidence of surface disintegration, did not dissolve and form sediment in this manner.

It is probable that the material that dissolved from this old concrete was lime hydrate which changed to lime carbonate at the surface on exposure to the air. Lime carbonate being less soluble, it was then precipitated and the action repeated. Although all the cements used had passed the standard tests, some, when incorporated in concrete, were less soluble than others.

THOMAS H. WIGGIN,* M. AM. SOC. C. E.—Mr. Flinn has mentioned certain troubles that occurred on the Catskill Aqueduct. The speaker is familiar with the work on the Eastview Tunnel, which was driven through rock that contained iron pyrites. This mineral was the source of hydrogen sulphide, which gave considerable odor and was evidently present in the ground-water.

About two years after this tunnel had been concreted, it showed signs of disintegration in a stretch about 1 500 ft. long. The engineer, in walking through it, happened to notice a surface defect and was surprised to find that he could drive in a bull-point a few inches in some places, and a foot in others. A systematic examination revealed many soft places, the largest of which were in the arch, where, at one point, a cubic yard or more of concrete was removed. The concrete was so changed in structure that one could make a ball of it, somewhat similar to partly set lime mortar.

The cement was damaged, apparently, in some way by the sulphurous or sulphuric acid in the water, and the action may have been quite similar to that of sea-water sulphates, although the exact chemical action was never really determined.

In repairing this stretch, a bituminous water-proof lining was placed inside the tunnel for about 1 600 ft., against which was laid a 12-in. lining of vitrified brick. Subsequently, thorough grouting was done both outside the original lining and between the linings.

Similar alteration of the concrete occurred in other parts of the aqueduct, but in very small patches, and, in general, there was some suggestion of hydrogen sulphide. Some of the concrete exposed in the open air, notably that in the spillway of the Ashokan Reservoir, disintegrated from the surface downward without any cause such as was apparent in the tunnels. The concrete in the spillways was given more study than that in the tunnels. The reports of Mr. Howes, and Professor Colony, who studied it rather exhaustively, are on file and doubtless are available.

Thanks are due the authors for their compilation of information on the subject from the time of the early French investigators to the present. The speaker has often found in studying subjects of this kind that considerable information had been obtained by engineers or scientists many years ago, which had been neglected, although it could be studied with profit by the present generation and with saving of duplication.

The speaker would like to ask the authors to make a few remarks on the experiments which are described on page 9,† which seem to be somewhat at variance with the remainder of the information.

* Cons. Engr., New York, N. Y.

† *Proceedings*, Am. Soc. C. E., August, 1923.

ROBERT RIDGWAY,* M. AM. SOC. C. E.—That part of the Lexington Avenue Subway in New York, N. Y., which passes under the Harlem River, was built by the so-called trench method, somewhat as the Michigan Central Railroad Tunnel was constructed under the Detroit River. The steel tubes enclosing the four trackways were sunk in place in a dredged trench, after which they were surrounded by 1:3:6 concrete placed by the tremie method. The concrete was placed in 1914 and 1915, and it occurred to the speaker in 1920 that, as the Harlem River is a sewage-laden, salt-water channel, it would be desirable to obtain a shot-drill core from the concrete to ascertain its condition. Provision for this was made, therefore, in one of the Transit Commission's boring contracts, but when the time came to do the work, the officials of the operating company requested that the boring be not made, because of the fear that through some error or carelessness the steel tubes might be punctured and the tunnels flooded. Consequently, the core was not obtained, and there is no direct evidence of the condition of the concrete, although nothing has occurred to indicate that it is not sound.

In driving the shields for the East River Tubes of the Rapid Transit Subway at the foot of Old Slip, Manhattan, about 1916, the concrete of the bulkhead wall constructed by the Department of Docks about 10 years before was encountered, and a substantial quantity of the concrete within the cross-section of the shields was taken out. The foundations of the wall consisted of concrete deposited in burlap bags, on top of which, large precast blocks of the standard type of the Department of Docks were placed. The concrete was dense and sound, especially that which was precast, and showed no signs of disintegration. The precast concrete was blasted out, whereas that deposited in the bags was removed by pneumatic "bull points", or chisels.

RICHARD H. GAINES,† ESQ.—Few subjects have received more careful study than the action of sea water on concrete. In spite of this, no sure means of preventing disintegration have been found. At present, no cement can be considered safe against the action of sea water. Portland cement as now constituted is inherently subject to attack, and the best quality of mortar or concrete may be disintegrated in time.

Two causes militate against the permanency of concrete in sea water in this latitude. One of these causes is frost action, the water absorbed at high tide freezes at low water, which causes the surface to spall away between the tide levels. Added to this is the erosive action of ice. The other cause, vastly more destructive, is primarily a chemical action, rather than a physical disruption. This action takes place between certain salts in sea water, chiefly magnesium sulphate and constituents of the cement. Magnesium sulphate re-acts especially with the calcium hydrate or free lime liberated during the process of setting, forming compounds that swell and are partly soluble. In this way, the damage is done. If concrete is rough and porous, sea water will gradually eat into the heart of the structure and decompose the Portland cement it contains.

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† Chemist, Board of Water Supply, New York, N. Y.

It is well known that if ordinary fresh water is allowed to percolate through concrete, some of the lime compounds are slowly dissolved. Soluble sulphates, if present in the percolating water, render it more energetic, and the disintegrating effect is considerably increased. It was deemed of interest to establish a quantitative percentage relation between the solvent action of ordinary water, and water containing about the same quantity of sulphates as found in sea water. No previous record could be found of an attempt to determine the quantitative percentage increase of the deteriorating action of sea water as measured by increased quantities of lime dissolved.

For the experiment, seven cement products were taken, including a sample of Portland cement, mortar briquettes, hydrated lime, calcium aluminate, calcium silicate, and calcium carbonate. All the materials were finely ground, or in a powdery condition. A 30-gram sample of each was agitated in glass jars for 3 days in 300 cu. cm. of New York City water, and jars containing a like quantity of city water to which was added about one-half of 1% of magnesium sulphate. At the end of the 3-day period, 100 cu. cm. of each solution was filtered off and the quantity of lime present determined, as calcium oxide. The results are given in Table 2.

TABLE 2.—ACTION OF 0.5% OF MAGNESIUM SULPHATE SOLUTION ON THE CALCIUM COMPOUNDS IN CEMENT AND CEMENT PRODUCTS.

The Figures Show the Weights of Lime Found in Each 100 Cu. Cm. of Solution.

3-day tests.	WEIGHT, IN GRAMS, OF CaO.		Percentage increase of lime dissolved.
	Water.	Water + 0.5 % magnesium sulphate.	
Edison cement mortar briquette, 28 days old. Dried and ground	0.087	0.145	66
Lehigh cement mortar briquette, 3 days old. Dried and ground	0.063	0.119	90
Lehigh cement	0.144	0.200	39
Hydrated lime	0.128	0.192	50
Calcium aluminate	0.035	0.043	23
Calcium silicate	0.010	0.030	200
Calcium carbonate	Trace	Trace	...

It will be noted from Table 2 that the city water attacked all the samples except calcium carbonate and dissolved various quantities of lime.

The results show an average increased solvent action of 65% by the water containing 0.5% of magnesium sulphate over ordinary water, and, as far as they go, confirm the statements of the authors and Vicat and others that the presence of this salt in water materially hastens the disintegration of cement.

Portland cement concrete is fairly durable in sea water, provided certain reasonable precautions are taken. These precautions include careful choice

and inspection of materials, a watchful grading of aggregate, and a dense mixture. It was long believed that a cement high in silica and low in alumina was best suited for use in sea water, but recent experiments with high alumina cements have given results that throw doubt on this point.

Concrete of good quality is the most resistant to disintegrating action. High quality is measured by impermeability, or resistance to the passage of water through the mass under pressure. The important factor in obtaining impermeability is rich cement content. High compression strength can generally be used as a criterion for high impermeability.

Unless the structure is impermeable, conversion of the lime into carbonate at or near the surface will not prevent disintegration, although it may delay it. The carbonate, although slowly affected, is permeable, and the uncarbonated parts within may be attacked, resulting in the shelling of the carbonated surface.

The use of membrane water-proofing will prevent action for a time at least, but such a method is not practicable under all conditions. Tar coatings are not permanent.

The disintegration of concrete in chloride or carbonate waters in the absence of sulphates appears to be very slow, or almost lacking.

J. R. SLATTERY,* M. AM. SOC. C. E.—The United States Engineer Department is working along the principle of obtaining dense concrete, and its members are much interested in investigations of the kind undertaken by the authors. At present, however, it is felt that, as stated by Mr. Gaines, dependence must be placed on the use of the densest possible concrete and precast sections wherever possible. Nevertheless, it is believed to be the chemist to whom the Engineering Profession must look for solving the problem of cements that will withstand sea water.

KENNETH ALLEN,† M. AM. SOC. C. E.—It is quite well understood that concrete is subject to deterioration under certain circumstances and the question arises: What will become of all the concrete used in sewers? Concrete is a standard material used in building sewers, and sewage is a much more variable kind of liquid than sea water, drinking water, or stream water; and the speaker thinks that its possible effect on concrete is a serious question that should be studied more carefully than it has been in the past. He does not think it has been realized what the action on concrete of different sewages may be, although it is gradually becoming known that deteriorations are taking place. Two or three instances have come to his attention and no doubt there are a great many more, because sewer structures are not often carefully examined unless they fail.

The deleterious action of septic sewage on concrete has been recognized ever since the disintegration of the outfall sewer at Los Angeles, Calif., was observed about 23 years ago. Similar results have been noted in the septic tanks at Amherst, Ohio, Saratoga, N. Y., and Hampton, England and in

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concrete pipe or drains in Brooklyn, N. Y., Great Falls, Mont., Nuneaton, England, Madras, India, Berlin, Germany, and elsewhere. This disintegration appears to be due to the evolution of hydrogen sulphide through the action of certain kinds of bacteria on sulphate-bearing sewages.

The hydrogen sulphide thus liberated, is oxidized when brought in contact both with the air and the wet surface of the concrete, and probably in the form of sulphurous acid attacks the calcium silicate, and more particularly the calcium aluminate, of the cement, forming sulphates of alumina and calcium with a residual deposit of free sulphur in some cases. These sulphates either dissolve and are removed by the current, thus exposing the fresh concrete to further attack, or crystallize and by expansion destroy its integrity. Hydrogen sulphide, being heavier than air, tends to remain near the surface of the sewage with the result that disintegration is most active at that level. Therefore, it would at least appear desirable to protect the interior of concrete sewers carrying septic or stale sewage with a lining of vitrified tile or brick, particularly in those cases where the water supply is rich in sulphates.

Mr. Wiggin has mentioned a case where the outside surface was hard and the interior was soft, like putty. There was a case at Pier 6 on the East River, New York, N. Y.—the State pier—in which that condition was duplicated. The outside shell was hard and smooth; the concrete had evidently been good when it was placed, but chemical action took place underneath the shell, and inside, for 1 or 2 in., it was quite soft.

The question confronting the engineer is the practical one of selecting a cement on the market having a composition that will serve his purpose. He cannot produce off-hand all the chemical conditions that might be desirable. One point that the speaker thinks is sometimes overlooked, when the question of using concrete piling or wooden piling is considered, is that it is often assumed that the concrete pile is going to fail. This is also true of the wooden pile. It is a matter of relative durability. The concrete pile may last longer, but it is a question of deterioration—amortization.

The speaker believes that with great care in construction, the use of concrete in sea water is often to be recommended. There are cases where it is known to be in excellent condition after many years; for example, the boardwalk at Atlantic City, N. J. The columns are in excellent condition, and some of them have been in use about 14 years. In other places where concrete has been exposed to sea water for a short time, it has disintegrated; but it is probable in most instances that, if all the circumstances were known, one could point out the cause of failure.

There are many possibilities of failure: from the composition of the cement and the mix to the character of the material, the workmanship, and the placing of the reinforcing material. If all these conditions are cared for, the speaker thinks that in most cases the structure should last well, as compared with one built of other materials.

About two years ago, because of the disintegration of concrete in the piles supporting the Municipal Bath House at Coney Island, and the fact that a large expenditure of money was anticipated in the construction of the

Coney Island Boardwalk and a boulevard crossing Jamaica Bay, the speaker was requested by Arthur S. Tuttle, M. Am. Soc. C. E., Chief Engineer of the Board of Estimate and Apportionment, New York, N. Y., to investigate the durability of concrete—more particularly reinforced concrete—exposed to sea water. Various marine structures of concrete were inspected, engineers conversant with such work interviewed, and a search was made of the literature of the subject. The opinion was expressed:

"That the unfortunate results observed in many structures have been due to causes which are now recognized as preventable and that it is largely a question of the ability to secure rigid control of construction methods that should determine whether this material should be adopted or rejected in any given work."

The Boardwalk, costing nearly $2 000 000, was placed in service in the spring of 1923 and the Jamaica Bay Boulevard is under construction.

The speaker would be glad if some information could be gained on the importance of a low alumina content for cements exposed to sea water. Contrary to the results which appear to have been found in the use of *ciment fondu*, Le Chatelier considered that,

"Aluminous compounds present in Portland cement are the direct cause of its destruction by sea water * * *. Cements containing 1 or 2% of alumina are, for example, practically unaffected by sea water, while in cements containing as high as 7 or 8% of alumina the swelling and consequent disintegration are very rapid."

In this most recent study by the Committee on Marine Piling Investigations under the direction of Col. Atwood, there appears to be much hope of bringing about a truer and more general appreciation of the causes of failure in concrete in contact with sulphate-bearing waters and some practicable means for its prevention.

JOHN CHARLES RIEDEL,* M. AM. SOC. C. E.—The Engineering Profession at large will congratulate the authors on the introduction of this subject which is undoubtedly as timely as any that could be presented for consideration.

The Borough of Brooklyn has about 400 miles of concrete pipe sewers which were built between 1860 and 1906. In 1903, the speaker replaced a concrete pipe sewer which had been laid about 1878 in Palmetto Street, near Knickerbocker Avenue. During the twenty-five years the sewer had carried the liquid wastes of a number of manufacturing plants, one in particular being the Welz and Zerweck Brewery. A considerable number of residences were also connected to the sewer, so that the flow, although characteristic of the ordinary district, during certain hours of the day, was, at other times, rich with industrial wastes. The concrete pipes removed (about 1 000 lin. ft.) were found to be in various physical conditions; some of them were perfect, some were in a crumbling condition, and the inverts of others were worn or reduced to the thinness of paper. It was evident that the pipes were laid at about the same time and likewise that they were all manufactured at about the same time and of similar material. They were hand-made Pierson pipes, the

* Cons. Engr., Brooklyn, N. Y.

cement used being Rosendale. The soil was of loam and clay, with occasional pockets of sand.

The reason that some of the pipes should have withstood the wear to which they were subjected, whereas, others failed completely, is a problem that has puzzled the engineers of Brooklyn for many years. The Palmetto Street sewer is not an isolated case, but was so striking that it made an impression that has not been forgotten.

Other concrete pipes have been replaced in Brooklyn and the story is the same, some of the pipes have failed and others have done all that could reasonably be expected of them. The experiences caused those in authority in Brooklyn to look on unlined concrete structures for sewerage purposes with suspicion and because of this, the practice of lining all concrete structures either with vitrified brick or vitrified plates has been followed.

The more that can be learned about cement and its behavior in structures, the more will its ultimate value be appreciated. The speaker has no fear for the strength and life of a cement structure that is not subjected to the varying conditions which obtain in sewers, but it is believed that the use of unlined inverts in sewers is open to serious criticism.

The effects of sea water on concrete were discussed in the report to the Board of Estimate and Apportionment of the City of New York by the Chief Engineer, in connection with the proceedings for the construction of the Coney Island Boardwalk. The previous speaker, Mr. Allen, had a large part in the preparation of the report which had an important bearing on the type of pile selected for the walk. The decision was in favor of concrete piles which have been successfully made and put in place. In order to insure ample protection for the steel reinforcement bars, a 3-in. covering of cement was specified and obtained. It is believed that all the available facts concerning action of sea water were incorporated in the report.

Charles Rufus Harte*, M. Am. Soc. C. E.—The breakdown of concrete—the expression is used advisedly—is something that occurs, not only as the result of exposure to salt water, but also as the result of various other conditions, and it has been the speaker's experience, that there are no fixed rules under which such action occurs. It is necessary to consider the subject rather broadly because the several principal causes are quite likely to play important parts in the disintegration of cement in sea water as well as in other places.

About twenty years ago, E. H. McHenry, M. Am. Soc. C. E., who had just come to the New York, New Haven and Hartford Railroad Company as Vice-President in charge of engineering and construction, had an extensive and thorough study made of the behavior of concrete in salt water, to determine whether concrete could not be substituted for the more costly stone masonry which, to that time, had been the standard construction. The evidence then obtained was contradictory and disappointing. Concrete of apparently the same general degree of excellence, and under quite similar conditions, in one place was satisfactory whereas in another, it had failed seriously. The agreement was quite uniform that, in water, the chief trouble occurred in the

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zone extending a little above, and a little below, the mean water level. As the result of the investigation, it was deemed wise to protect a concrete center by a facing of stone.

There seem to be two, and perhaps three, principal types of failure. In some cases, there is an internal chemical action which results in the formation of a soft mass behind an apparently unaffected face. This type of failure seems to be principally in concrete which has had a mortar facing, and the breakdown is largely dependent on the integrity of the facing, possibly because it retains some of the heat of the reaction, or perhaps by excluding the air. After the facing breaks down, the formation of the soft material is greatly checked, if not entirely stopped. The fact that mechanical breakdown usually follows, however, may hide the action.

Mechanical breakdown may result from blows and abrasion, as from floating ice or drift. It may be caused by water entering crevices and holes in porous concrete and freezing, small particles being crushed or sheared off on the resulting expansion. Where the concrete is exposed to wave action, disintegration may be caused by the hydrostatic pressure produced in interior cavities full of water by the impact of waves on water in small passages leading from the outside to the larger cavities.

There is also a form of breakdown in the open that may be a third principal type, in which the action is much like the chemical failure. Unlike it, however, there is no protecting face, the outside concrete failing first. Although the concrete crumbles, it lacks the slimy consistency of the other form, and has little if any odor. These two apparent differences, however, may be due merely to the fact that, in the absence of the protecting skin, the creamy paste is washed away as fast as it forms, and, similarly, the odor is blown away. The speaker believes that the two actions are quite different, but he has no definite proof of this.

The entire subject is of great importance, and particularly as it affects reinforced concrete. Injury to mass concrete usually can be repaired with little difficulty, provided it has not been too badly neglected. Disintegration, however, soon exposes the steel in most reinforced concrete structures and the resulting corrosion can be made good only at large expense. There is considerable difference of opinion about many of the factors, but there is one point on which the agreement is almost unanimous, that is, that if concrete is made dense, there is the least likelihood of disintegration, and many engineers of large practical experience are satisfied that with the present cements, dense concrete is dependable.

The authors are to be congratulated on their paper, and it is greatly to be hoped that the discussion will furnish a fund of information. The fact that quite different types of action seem to be involved, makes it desirable that all pertinent facts be available for further study.

CHANDLER DAVIS,* M. AM. SOC. C. E. (by letter).†—The authors have added a valuable paper to the literature on the use of cement in maritime structures.

* Cons. Engr., New York, N. Y.

† Received by the Secretary, July 2, 1923.

The subject is one of the greatest importance, one which should be thoroughly studied, even more than it is to-day, during the actual building of structures which are to be exposed to the action of water, whether it is salt or fresh. The writer believes that, in addition to the usual tests of the cement to determine its strength, etc., it should also be analyzed. The sand, gravel, and broken stone of each delivery should likewise be analyzed in the same careful manner. Samples of the water in which the concrete is to be placed, should also be analyzed from time to time. In fact, as complete a record as possible of the materials used and of the meteorological conditions under which the work was done, should be preserved so that any future study made of the work, will be based on complete and accurate data. This may seem to be burdening the engineer with a great deal of additional labor; in reality, a few minutes a day would enable one man to keep these records up to date. Unfortunately, this has not been done, and it is difficult, therefore, to determine the causes of the disintegration of some structures, whereas others, apparently built under the same conditions, have withstood the action of the elements.

The cause of the deterioration of concrete structures exposed to the action of sea water has been discussed by the authors. There is no doubt, however, that a dense impervious concrete will resist the action of salt water better than one which is not so dense. It has been the custom, therefore, particularly in Europe, to make the outer exposed surface of a richer mix than the interior concrete. This method is used by the French and Italian engineers. Luigi Luiggi, Hon. M. Am. Soc. C. E., Inspector General of the Royal Corps of Civil Engineers, Italy, has advocated such a method for many years; he further calls for the addition of pozzuolana, the quantity varying with the locality. An examination of several of the works of Mr. Luiggi showed that they were withstanding the action of the waters of the Mediterranean and that the surfaces did not show any signs of deterioration.

Concrete blocks made on land and cured before placing in the work will resist the action of salt water better than concrete placed *en masse in situ*. Both methods have been used in the Department of Docks, New York, N. Y., the latter method, however, with poor results. When the late G. S. Greene, Jr., M. Am. Soc. C. E., was appointed Engineer-in-Chief of the New York Dock Department, in 1876, he made a thorough examination and study of the sections of the river wall, which had been built up to that time. The result of this investigation was his well-known design for the bulkhead wall. The blocks of this wall weighed from about 76 to 90 tons each, and were manufactured on shore and placed on the pile or rock foundations by derrick. Examinations of this work from time to time, have not revealed any deterioration, regardless of the condition of the river waters.

The mixture of the concrete cannot be specified and rigidly adhered to, for any particular work. If an impervious concrete is desired, the quantity of cement used should exceed the voids in the sand and the quantity of mortar, those of the stone. Experience has proved that better results will be obtained if pozzuolana is added to cement that is to be used in sea water.

Erosion due to waves cannot be guarded against, as even the hardest rocks are slowly worn away by water constantly beating against them, nor can the

action due to floating ice be prevented. The gradual eroding action of the ice on concrete may be studied in the arches of Pier No. 1, North River, New York, N. Y., in which deep channels have been cut in the concrete arches, whereas the granite facing stones at either end of the arch show no signs of wear. This pier was built about forty-five years ago.

ALFRED H. WHITE,* ESQ. (by letter).†—There can be no question of the destructive effect of the chemicals in sea water on Portland cement under laboratory conditions. If, however, the chemical action is the chief disintegrating influence, disintegration should be greatest below the level of low tide where the concrete is constantly exposed to the sea water. The usual opinion is that disintegration is greatest at the level between high and low tide. It is reported that this holds true even in California where the temperature does not fall to the freezing point and the action of ice is, therefore, eliminated.

The authors have not considered the initial formation of hair cracks through expansion and contraction. The changes in volume due to moisture are several times as great as those due to ordinary alternation of temperature, as has been shown by the writer.‡

It seems at least plausible that the disintegration in the level between high and low tide is due to hair cracks formed by alternate expansion and contraction caused by the change of moisture content with the change in tide. These hair cracks would remain filled with water as the tide fell, and the salts would concentrate as the water evaporated. Chemical action would thus take place not only on the surface of the concrete, but also at progressively greater depths. If the water froze in the hair cracks, the disintegration, of course, would be correspondingly greater.

The remedy would appear to be the prevention of hair cracks. One of the most feasible preventive measures is the use of water-proofings. Coatings are good while they last. Integral water-proofings of the water-repellent type help materially and, if properly used, do not weaken the concrete in serious measure.

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* Prof. of Chemical Eng., Univ. of Michigan, Ann Arbor, Mich.

† Received by the Secretary, July 9, 1923.

‡ "Destruction of Cement Mortars and Concrete Through Expansion and Contraction," *Proceedings*, Am. Soc. for Testing Materials, Vol. 11, pp. 531–555 (1911).
"Volume Changes in Portland Cement and Concrete," *Proceedings*, Am. Soc. for Testing Materials, Vol. 14, pp. 203–241 (1914).
"Volume Changes in Concrete," *Transactions*, International Eng. Cong., San Francisco, 1915, Engineering Construction, pp. 242-273.

MEMOIRS OF DECEASED MEMBERS

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

CHESTER HARVEY CHAMBERLIN, M. Am. Soc. C. E.*

DIED JULY 14, 1922.

Chester Harvey Chamberlin was born at Natchez, Miss., on September 14, 1859. After his preliminary schooling, he received a four-year Classical Course at Stewart College, Clarksville, Tenn.

In 1881, he entered the service of the American Railway and Improvement Company, as Rodman and, later, as Instrumentman, making surveys in Mississippi, Louisiana, and Texas, and, during 1883 and 1884, he served as Resident Engineer on the construction of the Yazoo and Mississippi Valley Railway in Louisiana and Mississippi.

In the latter part of 1884, Mr. Chamberlin became Locating Engineer for the Guatemala Northern Railway, in Guatemala, where he remained until 1886. He then returned to the United States to accept a position as Special Timber Agent, with the U. S. General Land Office, in Minnesota, where he served until 1889. During 1889 and 1890, he was engaged as Third and Second Assistant Engineer and Acting Division Engineer for the Nicaragua Canal Construction Company, in Nicaragua, returning to the United States in 1891.

In 1891, Mr. Chamberlin entered the service of The Texas and Pacific Railway Company, with which Company he remained until April, 1917, serving as Assistant Engineer on Location and Construction, Division Engineer in Charge of Maintenance, Assistant Chief Engineer, and Chief Engineer, respectively. During 1917, and until 1920, he was engaged in constructing short-line railways in Texas and afterward became the senior member of the Chamberlin-Woodward Construction Company, of Eastland, Tex.

He was exceptionally modest and unassuming in manner, but his sterling worth soon impressed those with whom he came in contact. He was married in 1903 to Miss Jennette Woodward, of Thibodaux, La., who, with two children, survives him.

Mr. Chamberlin was elected a Member of the American Society of Civil Engineers on October 4, 1904.

WILLIAM GEORGE COMBER, M. Am. Soc. C. E.†

DIED APRIL 8, 1923.

William George Comber was born in London, England, on September 14, 1855. He was educated at the Ryde National School on the Isle of Wight.

* Memoir prepared by R. L. Holmes, M. Am. Soc. C. E.

† Memoir prepared by Lansing H. Beach, M. Am. Soc. C. E.

He came to the United States when a young man, and for a time was engaged in teaching school and farming in Indiana.

He began his engineering career in 1883 as an Axeman, under the United States Engineer Department, with one of the engineering parties of the Mississippi River Commission, at a salary of $30 per month, with board and lodging. He was soon made Recorder and stayed with the Mississippi River Commission until 1905, being, successively, Observer, Chief of Party, and Assistant Engineer. Most of the topographical surveys made by the Commission above St. Paul, Minn., were under his direction.

In August, 1905, Mr. Comber went to Panama with the Isthmian Canal Commission, where he remained for thirteen years. As Resident Engineer under the Pacific Division, he had charge of all dredging at the western end of the Canal. Later, after the completion of the Canal, Mr. Comber's duties were enlarged to include the supervision of all the dredging in the Canal prism. His greatest work was the removal of the slides which closed the Canal shortly after it was opened. This important work was handled with the greatest expedition and skill.

He resigned his position with the Canal Commission on October 11, 1918. Shortly thereafter, he was employed by the Construction Division of the United States Army, in charge of dredging operations at the Army Supply Bases in Boston, Mass., New York, N. Y., Philadelphia, Pa., and Charleston, S. C.

Mr. Comber came to the Office of the Chief of Engineers as Consulting Engineer on Dredging in 1919. In this position, his wide experience and intimate knowledge of dredging made his services of great value to the Engineer Department. He spent most of his time in the field, visiting the various dredging plants all over the United States and doing the work of standardizing and co-ordinating the operations of the various Districts. Much of the credit for the greater economy that has been secured by the Engineering Department in its dredging costs during the last few years is due to Mr. Comber, as the result of this constant field supervision. During the last four years, many improvements in the design of dredges have been worked out in the Office of the Chief of Engineers, and Mr. Comber's practical suggestions helped greatly in this work.

Mr. Comber's death occurred at New Rockford, N. Dak., while on the train *en route* from Portland, Ore., to Madison, Wis., on leave of absence. While in San Francisco, Calif., in February, 1923, on one of his inspection trips, he was taken ill and had been for a time in St. Mary's Hospital in that city. He is survived by his wife, Mrs. Hallie Belle (Gilbert) Comber, by his son, William G. Comber, Jr., and his daughter, Mrs. A. H. Wait.

He was highly regarded by all who knew him as an able and conscientious worker and a generous and delightful friend. In his death, the Society loses an engineer of high attainments and of sterling character.

Mr. Comber was elected a Member of the American Society of Civil Engineers on June 24, 1914.

BENJAMIN FRANKLIN CRESSON, JR., M. Am. Soc. C. E.*

DIED JANUARY 25, 1923.

Benjamin Franklin Cresson, Jr., the son of Benjamin Franklin and Martha (Chambers) Cresson, was born in Philadelphia, Pa., on October 23, 1873. He was educated at Lehigh University and the University of Pennsylvania, from which latter institution he was graduated as a Civil Engineer in 1894. His first engineering work was with the Lehigh Valley Railroad Company at Wilkes-Barre, Pa.

From 1897 to 1899, Mr. Cresson was engaged on the tunnel and subway work of the Reading Railroad Company in Philadelphia. In the spring of 1899, he came to New York City, where he began an association with J. Vipond Davies, M. Am. Soc. C. E., which lasted for many years, and much of the information contained in this memoir was received from Mr. Davies. At that time (1899), work was being resumed on the old Hudson River Tunnels which had been abandoned in 1891. Included in the first work undertaken by Mr. Cresson was a re-survey and re-inspection of the work on the tunnel between the foot of Morton Street, New York City, and 15th Street, Jersey City, N. J. This work was not only difficult, but was attended with considerable danger. On the completion of this inspection, he took charge of the location of bridges on the West Virginia Short Line Railroad. He also made surveys and studies for a water terminal for that Company, on the Ohio River, which constituted his first introduction to that field of engineering which afterward became his life work.

Returning to New York City, Mr. Cresson was engaged on investigations contemplating the extension of the Long Island Railroad into the Borough of Manhattan. During this and other investigations, he rendered exceedingly valuable service. He was afterward assigned to the construction of the Atlantic Avenue Improvement in Brooklyn, N. Y., which resulted in the removal of the tracks of the Long Island Railroad from the street surface. The complete and comprehensive base-line survey, from which the entire work was executed, was made by Mr. Cresson.

Then came the great Pennsylvania Railroad improvement, the construction of its station on Manhattan Island and the tunnels under the Hudson and the East Rivers. The borings in the Hudson River were under the immediate charge of Mr. Cresson, who, according to Mr. Davies, was the first engineer employed on the construction of the Pennsylvania Tunnels under the Hudson, and his service was continued until the completion of the work on the Terminal Station. The work of making borings under the Hudson River was begun in November, 1901. The entire triangulation work for the North River Division extending from Ninth Avenue, New York, to the westerly face of the Palisades, a distance of 25 000 lin. ft., and the detail topography, were done under his direction. Perhaps there is no more severe test of the accuracy of the work of the engineer than the planning and con-

* Memoir prepared by Nelson P. Lewis, M. Am. Soc. C. E.

struction of tunnels, and the results in this work furnished a splendid tribute to the capacity of the man in charge. Early in 1905, the preliminary work having been completed, Mr. Cresson assumed charge, as Resident Engineer, of the "Terminal-Station West", an open-cut excavation involving about 500 000 cu. yd., with 18 000 yd. of concrete retaining walls. This work was described by Mr. Cresson in a paper* which was presented before the Society at its meeting of April 6, 1910.

Up to the time of completion of the Pennsylvania Station, Mr. Cresson's energies had been concentrated on special problems involved in the entry of a trunk-line railroad into New York City. The broad field which later claimed his attention, was opened to him almost accidentally. Having completed the work which he had done so well, he was looking for another connection and, in January, 1910, hearing that the late Calvin Tomkins, Assoc. Am. Soc. C. E., was looking for a Superintendent to take charge of his stone quarries on the Hudson, Mr. Cresson called on him in regard to this position. Mr. Tomkins had lately assumed the office of Commissioner of Docks of New York, by appointment of the late Mayor Gaynor. After Mr. Cresson had outlined his experience, Mr. Tomkins said to him, substantially, "I am looking for a man to take charge of these quarries, but I also want some one to come with me as Deputy Commissioner of the Dock Department. I want some one with the kind of engineering experience you have had, and I would like you to accept a position as Deputy Commissioner of Docks rather than one as Superintendent of those quarries". Thus, began Mr. Cresson's close study of the Port of New York, and any one familiar with what was done during the next few years will appreciate the intelligence and thoroughness of that study. During his incumbency of the position of Deputy Commissioner, he visited a number of European ports, and his report published in 1912, describing more particularly the equipment of those ports, is a valuable public document.

Retiring from the New York Dock Department in May, 1913, he became Engineer of the New Jersey Harbor Commission. On July 1, 1915, he was appointed Chief Engineer of the New Jersey Board of Commerce and Navigation, becoming Consulting Engineer of the same body in February, 1917, and continuing to serve in that capacity until his death.

At the outbreak of the World War, Gen. George W. Goethals, M. Am. Soc. C. E., called on Mr. Cresson for his services in planning the Army supply storage plants necessary for the Quartermaster General's Department. For the greater part of the period during which the United States was engaged in the war, he was associated with Gen. Goethals in this work, a number of the base terminals located by him having been constructed.

At the same time, Mr. Cresson rendered most valuable service to the Shipping Board, in the development of plans for the Emergency Fleet Corporation, by his analysis of the port terminals of the United States, a field in which there was urgent need of skilled advice and information, which were freely supplied to the Board by Mr. Cresson.

* *Transactions*, Am. Soc. C. E., Vol. LXVIII (1910), p. 303.

When the New York-New Jersey Port and Harbor Development Commission was organized, Mr. Cresson was selected as its Chief Engineer, and the report of this Commission, submitted to the Governors of the States of New York and New Jersey in December, 1920, is a monument to his industry and capacity. This bi-State Commission was succeeded by the Port of New York Authority, and Mr. Cresson continued as Chief Engineer of the new body which he served with enthusiasm and devotion until his death, on January 25, 1923.

Mr. Cresson also contributed to the records of the Society, a valuable paper entitled "The Problem of the Lower West Side Manhattan Water-Front of the Port of New York",* for which, in 1913, he was awarded the J. James R. Croes Medal.

During the summer of 1922, he made another visit to European ports, the impressions gathered from which were described by him in an informal address at the meeting of the Society held on November 1, 1922.

A tribute, as unusual as it was deserved, was paid to his memory in the State House at Trenton, N. J., on February 19, 1923. This tribute was a memorial meeting at which addresses were made by representatives of both branches of the New Jersey State Legislature, of the Board of Commerce and Navigation, and of the Port of New York Authority, as well as by old friends and neighbors of himself and his family.

At the time of his death, Mr. Cresson was President of the Society of Terminal Engineers. He was also a member of the Institution of Civil Engineers and of the Institute of Mining and Metallurgical Engineers.

Those who had the opportunity of close personal association with Mr. Cresson had the privilege of knowing a man of rare personal charm and of the most lovable characteristics. What he accomplished is well known; the manner in which he did it, and the kind of ideals which he always kept before him, could have been known only to his most intimate personal and professional associates. After his death there was found in his desk a sheet of paper which had evidently been handled a great deal and which contained simply a quotation from Alexander Hamilton, reading as follows:

"Men give me credit for some genius. All the genius I have lies in this: When I have a subject in hand I study it profoundly. Day and night it is before me; I explore it in all its bearings. My mind becomes pervaded with it. Then the effort I have made is what people are pleased to call the fruit of genius. It is the fruit of labor and thought."

Although Mr. Cresson would have been the last to have classed himself as a genius, the mental processes and habits described in this quotation were conspicuously his.

Those who were privileged to acquire an intimate knowledge of Mr. Cresson's home life state that it was ideal and that the members of his family were as delightful and lovable as himself. Mrs. Cresson, who was Miss Amy Tuttle, of Tiverton, R. I., and a daughter, Cornelia, survive him. He is also survived by his father and mother and by three sisters.

* *Transactions*, Am. Soc. C. E., Vol. LXXV (1912), p. 226.

Mr. Cresson was elected an Associate Member of the American Society of Civil Engineers on April 2, 1902, and a Member on January 7, 1908.

JULIAN GRIGGS, M. Am. Soc. C. E.*

DIED DECEMBER 4, 1922.

Julian Griggs was born in Chaplin, Conn., on September 15, 1848. He was a member of the Class of 1869, of Sheffield Scientific School, Yale University, leaving college at the end of his Junior year.

Mr. Griggs began his engineering service on the Boston, Hartford and Erie Railroad, in 1869. In 1880, after serving a number of railroad companies in various capacities, exclusive of a five-year period following the panic of 1873, when he taught school and engaged in mercantile pursuits, he entered the employ of the Scioto Valley Railroad Company, the lines of which at that time extended from Columbus, Ohio, to the Ohio River, and now form part of the Norfolk and Western System. In that year, he located an extension of the Scioto Valley Railroad from Portsmouth to Ironton, Ohio, and, in the following year, he was appointed Chief Engineer, holding this position until 1890. Thereafter, he served the Norfolk and Western Railroad Company as Division Engineer of its Scioto Valley Division until 1897.

Mr. Griggs was appointed Chief Engineer of the Department of Public Improvements of Columbus, Ohio, in 1897, and retired in March, 1906. He later served as Consulting Engineer for Lancaster, Ohio; as Chief Engineer of the Scioto Valley Traction Company; and, at the time, he retired from active service in 1918, he was in the service of the Toledo and Ohio Central Railroad Company.

During his term as Chief Engineer of the Department of Public Improvements of Columbus, Mr. Griggs re-organized the Engineering Department of the city and did much toward taking the Department out of politics by eliminating political appointments and political assessments.

Following the flood of 1898, he prepared the plans and constructed the levees along the Scioto River. He also planned and constructed a large part of the sewerage system on the West Side of Columbus, and prepared the plans for other sewer extensions, many of which have since been constructed.

His enduring monument in the City of Columbus, however, is a series of great engineering works which, at the time of their construction, placed that city in the front rank the world over in the protection of the health of its inhabitants. These works which were inspected and studied by engineers of the United States and Europe consisted of the Scioto River Storage Dam, the Water Filtration Plant, and the Sewage and Garbage Disposal Plants. Mr. Griggs was enabled to complete only the Scioto River Storage Dam during his term of office; the others were under construction when he was removed from office by politics.

* Memoir prepared by E. H. Lee, M. Am. Soc. C. E.

Since his death, the City Council of Columbus has officially named the Scioto River Storage Dam the "Julian Griggs Dam". In a letter to the City Council, conveying the request of the Chamber of Commerce that this dam be named in honor of Mr. Griggs, the President of that organization said among other things:

"The Columbus Chamber of Commerce has noted the passing of the former City Engineer, Mr. Julian Griggs, and this event has brought to the minds of large numbers of the members a realizing sense of the tremendous indebtedness of the City of Columbus to this man. At a time when communities were far less informed than, in our day, on matters of water supply, sanitation, and sewage disposal, and when the public turned a rather cold ear to what it termed his theoretical ideas, he nevertheless fought for a period of ten years a steady unrelenting fight to have the city brought up to a first-class standard in these vital regards. We have done a great deal of boasting in Columbus in the last few years about the healthfulness of the city and about its being so fine a place in which to live and do business, but we are inclined to overlook the fact that it was very largely Mr. Griggs' insistence on these forward looking steps that has left us in the position we now occupy."

Mr. Griggs was a man of singularly direct and simple character. Modest and unassuming, he was tenacious in matters of principle. He not only professed himself a Christian, but he lived the Christian life. Young men who came under his direct influence were fortunate indeed. Greatly interested in engineering subjects himself, and a born teacher, he stimulated his subordinates by both precept and example. To his friends, it seemed that his standards of conduct were so high and so ingrained in his character that he was free from the uncertainties that beset the ordinary man in making the more important decisions of life. The wise, honest, and courageous decision seemed to be his automatically. To his friends, he was of the salt of the earth.

Mr. Griggs was President of the Columbus Engineering Society for a number of years.

He is survived by his widow, Mrs. Mary Davison Griggs, a son, Professor Robert Fiske Griggs, head of the Department of Botany, George Washington University, Washington, D. C., and two daughters, the Misses Dorothy and Julia Griggs.

Mr. Griggs was elected a Member of the American Society of Civil Engineers on October 4, 1899.

ROBERT WOOLSTON HUNT, M. Am. Soc. C. E.*

Died July 11, 1923

Robert Woolston Hunt was born December 9, 1838 in Fallsington, Pa. His father, Dr. Robert A. Hunt, of Trenton, N. J., was graduated from Princeton College in the Class of 1824, and, later, from the University of Pennsylvania. His mother was Martha Lancaster Woolston. Mr. Hunt spent several years learning the practical side of iron-making in the rolling mills of John Burnish and Company, at Pottsville, Pa. Later, he took a course in analytical

* Memoir prepared by Robert W. Hunt Company, Chicago, Ill.

chemistry in the laboratory of Booth, Garrett and Blair, on the completion of which he entered the employ of the Cambria Iron Company at Johnstown, Pa., and for that Company, on August 1, 1860, established the first laboratory in America as a direct part of an iron or steel organization.

In the fall of 1861, Mr. Hunt entered the United States military service, and was in command of Camp Curtin at Harrisburg, Pa., serving as mustering officer for the State of Pennsylvania, with the rank of Captain. In 1864, he assisted in recruiting Lambert's Independent Mounted Company, and was mustered into active service as a Sergeant, having tossed up with a friend who had also participated in recruiting the company, as to which one should receive a Lieutenant's commission. On being mustered out of service, Mr. Hunt returned to the employ of the Cambria Iron Company which sent him to the works at Wyandotte, Mich., where experiments with the new Bessemer process of making steel were being conducted. He was placed in charge of those works in July, 1865, and so continued until May, 1866, when the Cambria Company called him back to Johnstown to take care of its steel business, as the Company intended at once to begin the erection of a Bessemer steel plant. The plant, however, was not built for several years, and, in the meantime, the Cambria Company began the rolling of steel rails for the Pennsylvania Railroad, using ingots of Bessemer steel produced by the Pennsylvania Steel Company at its Steelton works. Mr. Hunt had charge of the steel for these operations, and, in August, 1867, the first steel rails ever made in America on a commercial order were rolled.

Later, Mr. Hunt assisted George Fritz, Chief Engineer of the Cambria Company, in designing and building the Bessemer works for the Cambria plant. On the completion of these works, on July 10, 1871, Mr. Hunt assumed charge, so continuing until August, 1873, when he resigned. On September 1, 1873, he moved to Troy, N. Y., where he was engaged as Superintendent of the Bessemer works of John A. Griswold and Company, and in March, 1875, he was made General Superintendent of the Albany and Rensselaer Iron and Steel Company, which had acquired the works of John A. Griswold and Company, and of Erastus Corning and Company. Subsequently, this organization became the Troy Steel and Iron Company, and Mr. Hunt remained in charge of it until April, 1888.

On leaving the Troy works, Mr. Hunt established the Bureau of Inspection, Tests and Consultation, now known as the Robert W. Hunt Company, and moved to Chicago, Ill., where the principal offices of the Company have always been located.

During the years of Mr. Hunt's active connection with steel rail manufacture at Troy, he almost rebuilt the various works and also erected a large blast furnace plant of the most complete character. Mr. Hunt individually, and in conjunction with John E. Fry, William R. Jones, Dr. August Wendel, and Max M. Suppes, patented various details of iron and steel metallurgical processes and machinery, among the most important of which were the first automatic rail-mill tables, which immediately became popular and were used under licenses by the majority of the rail mills in the United States.

Mr. Hunt served three terms as Commander of the John A. Griswold Post No. 338, G. A. R., of Troy. He was also a member of numerous technical societies among which may be mentioned the American Institute of Mining and Metallurgical Engineers (Honorary Member and twice President); American Society of Mechanical Engineers (Honorary Member and Past-President); Western Society of Engineers (Honorary Member and Past-President); Canadian Society of Civil Engineers; the Institution of Civil Engineers; the Institution of Mechanical Engineers; the Iron and Steel Institute of England; the American Iron and Steel Institute; and the American Society for Testing Materials (Honorary Member and Past-President).

In 1912, he was awarded the John Fritz Medal "for his contribution to the early development of the Bessemer process". Almost his last public appearance was at the Annual Meeting of the Western Society of Engineers on June 18, 1923, when he was presented with the Washington Award "for his pioneer work in the development of the steel industry in the United States and for a life devoted to the advancement of the engineering profession."

Mr. Hunt contributed many papers to the publications of the various societies of which he was a member. Among the most important of these papers may be mentioned the "History of Bessemer Manufacture in America" which was presented at the Centennial meeting of the American Institute of Mining Engineers on June 23, 1876; and "The Evolution of the American Rolling Mills", presented, as his Presidential Address, to the American Society of Mechanical Engineers on November 16, 1891. These two papers record with great accuracy many interesting facts concerning the development of the Bessemer steel process, and of rolling mills, in the United States, and they will unquestionably stand as Mr. Hunt's most important contributions. He especially will be remembered for his personal activities in the development of steel rails for modern use. He was the Secretary of the Special Committee of the American Society of Civil Engineers, which designed the Am. Soc. C. E. rail sections, and later he contributed largely to the re-design of various sections, and that now known as the Type "A" Section of the American Railway Association is virtually his work. He was a member of the Special Committee of the Society which is now investigating the stresses in railroad track.

Mr. Hunt's contact with rail manufacture was never lost, for necessarily his work in connection with the inspection of rails required the maintenance of an intimate knowledge of the various details of manufacture. In 1912, at the instigation of one of the most important of American trunk lines, his organization inaugurated the plan of rail inspection since generally known as "Special Inspection", which contemplates the most thorough supervision of the manufacture of steel and its rolling into rails that has ever been attempted, and the success of which has been unquestioned. As illustrative of Mr. Hunt's intimate touch with the steel rail problem, it may be mentioned that under date of August 1, 1921, he issued a public letter proposing a new rail specification, advocating again the nick-and-break test for soundness on each ingot rolled, or the alternative of making the top metal of the ingots into tie-plates.

In 1916, Mr. Hunt received the honorary degree of Doctor of Engineering from the Rensselaer Polytechnic Institute, of which he was a Trustee for many years.

On December 5, 1866, he was married to Miss Eleanor Clark, of Ecorse, Mich., who survives him. He died on July 11, 1923, at his Chicago residence and was interred in Oakwoods Cemetery, at Troy, N. Y., on July 14, 1923.

Mr. Hunt was elected a Member of the American Society of Civil Engineers on June 3, 1885. On July 10, 1923, the day before his death, the Board of Direction had nominated him for Honorary Membership in the Society.

WILLIAM ANDREW MAY, M. Am. Soc. C. E.*

DIED JUNE 1, 1923.

William Andrew May, the son of the Rev. Lewis and Louisa (Haines) May, was born at Hollidaysburg, Pa., on December 3, 1850.

He attended the public schools in the various places to which his father was called. When he was 14 years old, his father died and three years later, he lost his mother, and, from that time, his education was obtained through his own efforts. He attended Dickinson Seminary, at Williamsport, Pa., from which he received the degree of B. A. in 1873.

After leaving school, Mr. May entered the employ of the Hillside Coal and Iron Company at Scranton, Pa., as Assistant Mining Engineer. His ability was soon recognized, and he was appointed Chief of the Engineering Department, although he was only twenty-three years old. On September 1, 1874, he resigned this position, in order to continue his education. He entered the Junior Class at Lafayette College, Easton, Pa., from which he was graduated in 1876 with the degree of C. E. Three years later, he received his M. A. degree.

During his Senior vacation, Mr. May accepted the position of Topographical Engineer on the Pennsylvania State Geological Survey, but resigned to take charge of the Engineering Department of the Hillside Coal and Iron Company. In the spring of 1877, the Engineering Department of the Northwestern Mining and Exchange Company of Erie, Pa., was added to his duties, and, in 1881, he was made Chief Engineer of these Companies. Two years later, he was made Superintendent of the Hillside Coal and Iron Company, and, in 1898, he became Superintendent of the New York, Susquehanna, and Western Coal Company.

In 1901, Mr. May was appointed General Manager of the Hillside Coal and Iron Company, the New York, Susquehanna, and Western Coal Company, and the Pennsylvania Coal Company, and, in 1908, of the Northwestern Mining and Exchange Company of Erie, Pa., and of the Blossburg Coal Company. In 1911, he became Vice-President and General Manager of the five Com-

* Memoir prepared from information on file at Society Headquarters.

panies of which he was General Manager, and, two years later, he was elected to the office of President.

Mr. May was also identified with other large interests. He was Secretary and Treasurer of the Walburn Land Company and Secretary of the Schuylkill Anthracite Coal Royalty Company. For many years, he was a member of the Board of Directors of the Third National Bank of Scranton, of which, at the time of his death, he was Third Vice-President.

In addition to his numerous professional duties, he took an active interest in the local affairs of Scranton. He served efficiently on the Board of Education and, for five successive terms, was President of the Board of Trade. His brilliant administration stands out as the most important epoch in the history of the Board. As Vice-President of the Board of Trade Building Company, he was instrumental in bringing various large industries to the city, and to him is due the credit of promoting the erection of the 13th Regiment Armory, the Young Men's Christian Association Building and the Elm Street Methodist Episcopal Church.

Mr. May was an active member of the Methodist Episcopal Church. As President of its Board of Trustees, Superintendent of the Sunday School, and leader of a large Bible Class, he rendered valuable service. He was also Secretary of the Board of Trustees of the Young Men's Christian Association.

In 1878, he enlisted as a private in the 13th Regiment of the Pennsylvania National Guard, and ten years later, he was mustered out as Captain of Company D. While in this service, he won several medals for marksmanship.

Mr. May was married to Miss Emma Louise Richards, of Williamsport. Their only child, Mrs. James W. Page, of Slaterville, N. Y., and two brothers, George May, of Williamsport, and L. H. May, of Forest City, Pa., survive him.

He was a member of the Scranton Engineers Club, the Scranton Club, the Country Club, the Westmoreland Club of Wilkes-Barre, Pa., the Machinery Club of New York City, and the Masonic Fraternity.

Mr. May was elected a Member of the American Society of Civil Engineers on July 6, 1881.

GEORGE WASHINGTON PLYMPTON, M. Am. Soc. C. E.*

DIED SEPTEMBER 11, 1907

George Washington Plympton, the son of Thomas Ruggles and Elizabeth (Holden) Plympton, was born at Waltham, Mass., on November 18, 1827. He was a descendant of Thomas Plympton who came from Sudbury, England, on the *Confidence* in 1640, and who was one of the early settlers of Sudbury, Mass.

Mr. Plympton received his early education at the District School and afterward at the High School at Waltham, Mass., and his technical education at Rensselaer Polytechnic Institute, Troy, N. Y., from which he was graduated in 1847, with the degree of C. E. The degree of M. A. was conferred

* Memoir compiled from information on file at the Headquarters of the Society, and from data supplied by Theodore Belzner, Affiliate, Am. Soc. C. E.

on him in 1854 by Hamilton College, and that of M. D. in 1880 by the Long Island College Hospital.

He remained at the Institute for one year after his graduation, serving as Instructor of Geodesy and Mathematics. In 1852, he became Professor of Mathematics at the New York State Normal College, and from 1853 to 1862 held a similar position with the State Normal School at Trenton, N. J. During the Civil War, he was engaged in engineering work for the U. S. Government.

From 1863 to 1879, Professor Plympton occupied the Chair of Physics and Engineering at the Brooklyn Polytechnic Institute, Brooklyn, N. Y., and, for many years, was Director of the Night Schools at Cooper Union, New York City. He also served as Professor of Chemistry and Toxicology at Long Island College Hospital for twenty-one years.

He held the position of Editor of *Van Nostrand's Engineering Magazine* from 1870 to 1886, and among his contributions to technical literature may be mentioned "The Starfinder" published in 1878, and "How to Become an Engineer" published in 1892. He also revised and re-wrote a large part of Davie's "Surveying". He also contributed a paper to the *Transactions* of the Society, entitled "Some Experiments on the Transverse Breaking Strain of Plate Glass."*

Professor Plympton served as Commissioner of Electrical Subways of Brooklyn, N. Y., and was one of the Board of Experts selected in 1890 to improve the method of transportation across Brooklyn Bridge. His engineering work also includes the planning of the water supply and sewerage systems for Bergen, N. J., surveying the marl deposits of New Jersey, and the construction of iron bridges.

He was married in December, 1855, to Miss Delia M. Bussey, of Troy, N. Y., who died in 1858, leaving a son, Dr. Harry Plympton, of Brooklyn, N. Y. In 1861, Mr. Plympton married Miss Helen M. Bussey, the sister of his first wife, and they had three daughters.

Mr. Plympton was elected a Member of the American Society of Civil Engineers on January 29, 1868.

FRANK ARTHUR RAPP, M. Am. Soc. C. E.†

Died April 13, 1923.

Frank Arthur Rapp, the son of Frederick C. and Rachael Rapp, was born on February 5, 1876, in St. Louis, Mo., where his father was the representative of the Philadelphia Leather Company.

In his early boyhood, Mr. Rapp was very persistent in his effort to obtain an education, and, in this effort, he was assisted materially through the advice and financial assistance of Judge Dill, of St. Louis. His first inclination was directed toward the Medical Profession, but, later, he determined on a Civil

* *Transactions*, Am. Soc. C. E., Vol. XXV (1891), pp. 223, 227, 637.

† Memoir prepared by Charles M. Jenkins, Assoc. M. Am. Soc. C. E.

Engineering Course. He was educated in the Grammar School and Manual Training School of St. Louis, and the University of St. Louis, and received his B. S. and C. E. degrees at Washington University in 1898.

From August to December, 1898, and from May to December, 1899, Mr. Rapp was employed as Recorder with the Mississippi River Commission. From January to April, 1899, he served as Rodman, Draftsman, and Instrumentman, with the Chicago, Burlington, and Quincy Railroad Company, and from May, 1900, to April, 1904, with the Chicago, Milwaukee, and St. Paul Railway Company, one year as Assistant Engineer in charge (under the Resident Engineer) of surveying and computing in connection with the dredging of two slips for the Company's ore dock at Escanaba, Mich., and three years as Draftsman, Instrumentman, and Assistant Engineer, in the Bridge and Building Department, on the design of reinforced concrete abutments, culverts, falsework for arches, and trestle and steel girder bridges. As Assistant Engineer, Mr. Rapp had charge (under the Engineer of Masonry Construction) of bridge and building construction work on one of the Divisions of the road.

From about April, 1904, to November, 1906, he was engaged as Engineer of Mines for the St. Paul Coal Company, and was in responsible charge of surveys for four coal mines at Granville, Cherry, and Braceville, Ill., and the design and construction of a power plant and the erection of steel tipples for two new mines at Granville and Cherry (each of which produced 2 500 tons daily). From November, 1906, to November, 1907, Mr. Rapp was Engineer of Construction for the Stuart Beebe Company, in which capacity he had charge of the laying out of buildings and machinery for the Chicago Portland Cement Company, at Oglesby, Ill. From December, 1907, to January, 1908, he served as Draftsman on coal mine tipples for Roberts and Schaeffer Company, of Chicago, Ill., and from February to July, 1908, he was Instructor in Civil Engineering at the University of Idaho.

In July, 1908, Mr. Rapp was appointed Transitman on the location of the Copper River and Northwestern Railway, in Alaska, in charge of party, where he remained until December of that year. From January, 1909, to June, 1912, he was engaged with the Oregon-Washington Railroad and Navigation Company, for two months as Transitman, and afterward as Bridge Designer and Chief Draftsman in the Bridge Department, at Seattle, Wash. He designed wooden bridges and steel viaducts for one year and had charge of the design, as Chief Draftsman, of concrete and steel viaducts, retaining walls, and wooden truss bridges.

In July, 1912, Mr. Rapp was appointed Bridge Engineer of the City of Seattle, which position he held at the time of his death. As such, he was in charge of the design and construction of all city bridgework—wood, concrete, and steel. Three of the bridges built since 1914 were of the bascule type, aggregating in value more than $1 600 000.

Mr. Rapp was married on December 18, 1901, to Miss Ida N. Roth, of St. Louis, Mo., whose father was head of the B. Roth Tool Company. He leaves a wife and a daughter, Frances Ann.

He was affiliated with the Seattle Section of the Society, and also with the American Association of Engineers and the Pacific Northwest Society of Engineers.

Mr. Rapp was elected a Member of the American Society of Civil Engineers on June 16, 1910.

JULIO FEDERICO SORZANO, M. Am. Soc. C. E.*

DIED JUNE 25, 1923

Julio Federico Sorzano was born on October 25, 1852, at Santiago de Cuba, Cuba. He was educated in France and Belgium and was graduated from the Institut de l'Etat à Gembloux, Belgium, on July 25, 1872, with a degree in Civil Engineering.

In 1874, Mr. Sorzano became Assistant Engineer in charge of the Machinery and Industrial Department of the International Exhibition at Brussels. From 1875 to 1877, he was engaged in superintending the erection of the machinery and sugar apparatus in the Factoria Central Monserrato, in Dorado, Porto Rico, and was also General Manager of several sugar estates in Porto Rico and Cuba.

Although established in New York City since 1879, the greater part of his work was done abroad, principally in Cuba, Mexico, Porto Rico, Haiti, and the countries of South America. He specialized in the sugar and allied industries.

Mr. Sorzano designed and constructed a score or more of sugar-mills in Cuba and Porto Rico. He was a pioneer in that work and an acknowledged expert in matters pertaining to both the cane and beet-root sugar industries, having instituted a great many improvements in the agricultural and manufacturing phases of the industry. He also designed and constructed a great variety of industrial establishments in Cuba, Mexico, South America, and the United States, and did a large amount of engineering here in foundation, ventilation, and drying work. He constructed the first railway ever built in Venezuela, as well as two other railroads in the same country.

One of the first questions on which Mr. Sorzano was consulted in the United States was in connection with the foundations of the towers of the Brooklyn Bridge with which there had been considerable difficulty.

Mr. Sorzano took an active part in the Panama Canal controversy concerning the relative merits of the lock canal as against the sea level canal, and the water supply available for the former type. He was a member of the Committee appointed by the Chamber of Commerce of the State of New York to study the matter, and wrote a number of articles on the subject, for various newspapers and magazines. He also presented a paper on the subject before the Society, at its meeting of November 17, 1909, entitled "Water Supply for the Lock Canal at Panama".†

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* Memoir compiled from information on file at the Headquarters of the Society.

† *Transactions*, Am. Soc. C. E., Vol. LXVII (1910), p. 61.

Mr. Sorzano was a close student of Latin-American affairs and an ardent supporter of friendly and trade relations between those countries and the United States. In 1911, he organized and became President of the Pan-American Chamber of Commerce, dedicated to the fostering of relations between the United States and the South American countries, and continued as President of this organization until his death.

He was a member of the American Society of Mechanical Engineers, the Institution of Civil Engineers of Great Britain, the Société des Ingénieurs Civils de France, and the Chamber of Commerce of the State of New York.

Mr. Sorzano was elected a Member of the American Society of Civil Engineers on September 3, 1884.

HENRY AMERMAN YOUNG, M. Am. Soc. C. E.*

DIED APRIL 23, 1923.

Henry Amerman Young was born in Elizabeth, N. J., on November 6, 1876. After graduating from Cornell University in 1899, with the degree of Civil Engineer, he was engaged, for a short time, in railroad engineering in the East.

In 1900, he became Assistant Engineer in the Department of Parks and Street Cleaning of Havana, Cuba, and, later, Assistant Engineer in the Sewer and Water Department, where he was engaged in the design of a part of the new sewerage system for the City of Havana. He was also employed on the sewerage system for Casa Blanca, Cuba.

In September, 1902, Mr. Young became connected with the U. S. Engineer Department, first at Tuscaloosa, Ala., in the design of canal locks and, later in the same year, as Superintendent of Construction at Fort Washington, Md., and Fort Hunt, Va. In 1905, he was appointed Engineer in the United States Reclamation Service, in charge of the construction of the upper half of the Huntley, Mont., Irrigation Project, comprising the head-works, main canal tunnels, and various structures in connection therewith, and the upper half of the Distribution System.

Returning to Cuba during the second United States Intervention in 1906, with the Department of Public Works, he became Chief Engineer in charge of the design and construction of the complete water-works system for Camaguey, Cuba, and, during his residence there, acted as Consulting Engineer for various other water-works projects on the Island, including those at Nuevitas, Ciego de Avila, and Santa Cruz del Sur. On his return to the United States in 1909, Mr. Young became Chief Engineer of the Jobson-Hooker Company, General Contractors, of New York City.

In October, 1911, together with Howard E. Hyde, M. Am. Soc. C. E., he organized the firm of Young and Hyde, Civil Engineers, which was later incorporated as Young and Hyde, Incorporated, Contracting Engineers and

* Memoir prepared by Earle K. Knight, M. Am. Soc. C. E.

Exporters, of which he was Secretary, Treasurer, and General Manager at the time of his death.

Mr. Young died at his home in Maplewood, N. J., after a short illness, of pleuro-pneumonia, and is survived by a widow and two daughters. He was a man of sterling qualities and kindly disposition, commanding the respect of all with whom he came in contact.

He was a member of the New England Water Works Association and of the Maplewood Club.

Mr. Young was elected a Junior of the American Society of Civil Engineers on March 5, 1901, an Associate Member on December 2, 1903, and a Member on March 5, 1912.

JOHN ALEXANDER BRITTON, Affiliate, Am. Soc. C. E.*

DIED JUNE 29, 1923.

The life of John Alexander Britton was one of accomplishment and furnishes a remarkable example of devotion to public welfare. It is one to emulate. In the world of men he has made his mark.

John Alexander Britton, of Scotch-Irish parentage, was born in Boston, Mass., on October 9, 1855. He attended the public schools of Roxbury, Mass., until he was thirteen years of age. He left Boston with his parents for San Francisco, Calif., in 1868, by way of the Isthmus of Panama. He continued his education at the old Lincoln Grammar School in San Francisco. At the age of fourteen, young Britton left school to help support the family, his first work being in a grocery store, where he was engaged as general helper. After a few months, he sought a better place, becoming bookkeeper and cashier of a musical institute. Having musical talent, both vocal and instrumental, this affiliation strengthened his interest in both music and the drama.

He was always bright and energetic and displayed a desire to advance himself. Early evincing an inclination to become an engineer, he attended night school to further this end. Seeking greater opportunity, after a year at the musical institute, Mr. Britton resigned to take a clerkship in a law office and, after a few months there, he entered another law office in May, 1871, where he studied under the guidance of his new employers, continuing his night-school studies in the meantime. Active day work and night work long continued brought a breakdown, and in order to get out of doors, he accepted, in May, 1874, what he expected to be a temporary place as Collector and Meter Reader for the Oakland Gas Company. He planned to resume the study of law as soon as his health permitted, not realizing that chance had placed him in an industry which was to become for him a life work. Although his duties did not require nor demand it, Mr. Britton learned the practical side of the business by actual experience, beginning at the bottom, digging ditches, setting meters, trimming lamps, and, at times, taking a shift as operator. As the business developed and his duties became heavier, he gave

* Memoir prepared by A. H. Markwart, M. Am. Soc. C. E.

up his plans to study law and became Bookkeeper for the Company, rising steadily thereafter until, in 1883, he became Secretary of the Oakland Gas Company. In 1889, he was made Manager and Engineer of the Oakland Gas Light and Heat Company, and, after 1898, was its President. After he had been in the gas business for six years, the first electric light plant on the Pacific Coast was started in San Francisco. He immediately began the study of electricity and, in 1882, designed and built Oakland's first electric light plant.

It is interesting to know that the advancement of John Britton was parallel with the development of applied electricity. His entrance in the electric utility field commenced about the time that Edison started to develop his incandescent lamp. Mr. Britton saw the growth in the use of electricity which swept over the United States during the past two score years, and he was a leader in the electrical industrial movement in his home State and elsewhere during the past three decades. Hydro-electric generation and transmission were started in California, and, in 1902, a number of gas and electric companies in Central California were amalgamated into the California Gas and Electric Corporation, with headquarters in San Francisco. Mr. Britton came from Oakland to be the General Manager and was the first President of the new organization.

Further amalgamation of the gas and electric utilities of Central California took place, the Pacific Gas and Electric Company being organized in 1905. Mr. Britton was the first President of the Company, serving until 1908 when, at his own request, he was made Vice-President and General Manager and as such directed the operations of this public utility company, one of the largest in the United States engaged in supplying electricity, gas, water, steam, and street railway service.

Mr. Britton had a National reputation in the gas and electrical field and was regarded by the entire fraternity as the "Dean of the Electrical Industry". In his passing, after forty-nine years of service, the industry has lost a leader, endeared to those who knew him and nationally admired and respected for his worthy accomplishments.

From his earliest days, Mr. Britton showed an active interest in social, civic, and business affairs. He also kept in touch with church activities through a natural religious tendency, and, at one time, was organist and tenor of St. John's Protestant Episcopal Church in Oakland. His connection with fraternal organizations was both broad and creditable. He was a member of the Scottish Rite, a Knight Templar, Shriner, and Thirty-third Degree Mason. He also belonged to several other fraternal organizations. During the World War, he was Chairman of the San Francisco Chapter of the American Red Cross, a member of the Executive Committee of the Liberty Loan Board, and Chairman of its General Publicity Committee. He was also a Director of the Panama-Pacific International Exposition, member of the Commonwealth Club, and of many other civic and National organizations.

Mr. Britton was a Regent of the University of California, President of the Bohemian Club of San Francisco, and a member of the Pacific Union Club

and many other social organizations. His affiliation with technical societies included a charter membership in the American Gas Institute, membership in the American Society of Mechanical Engineers and in the American Institute of Electrical Engineers, and he was also Vice-President of the National Electric Light Association. Mr. Britton took an active interest in the technical societies to which he belonged and wrote many papers on utility operation and management. Under the Cyrus Fogg Brackett Lectureship in Applied Engineering Technology, he gave a lecture in April, 1922, on the subject of "Public Utility Development on the Pacific Coast" before the Engineering Faculty and students of Princeton University; and, at the time the Society held its Fall Meeting in San Francisco in October, 1922, he delivered the address of welcome. He was an accomplished speaker, and his addresses covered a wide range of subjects; on many occasions, his audiences would rise to their feet and voice spontaneous admiration.

On July 23, 1879, he was married to Florence Mitchell, of Oakland, Calif. He was a devoted husband and father, and, in his family life, he was particularly happy. He is survived by his widow and three sons and two daughters, Van Eastland Britton, John Alexander Britton, Jr., Emmett Nicholson Britton, Mrs. Florence B. Kellog, and Mrs. Alice Britton Keeffe, and fourteen grandchildren.

Self-trained and self-made, with an inquiring turn of mind and retentive memory, John Britton developed a broad vision. He had a sympathetic interest in the work and troubles of others and showed rare consideration of the hopes and aims of the many men who were associated with him. One friend and associate of twenty-five years standing, among other things, said of him:

"He had the quality of fellowship developed to an unusual degree. He would make other men's troubles his own, and his ear and his sympathy were at the command of all who enjoyed his acquaintance, no matter what their station in life. He was never too busy to give attention to the personal concerns of others, and he contrived in some way to take an active part in an ever-increasing number of enterprises, civic, charitable, social and others, where his ready grasp and his wise counsel proved of inestimable value. He furnishes a striking illustration of the truth of the saying that only a busy man has time for everything.

"He was the kindliest disposition the Almighty ever created. I verily believe that he was loved for himself and for what he was personally, apart from any consideration of his influence or position in life, more than any other human being who ever walked beneath the sun in California. * * * He was in popular demand everywhere within the sphere of his activities and his response was ever prompt, no matter at what personal inconvenience. He never spared himself.

"Perhaps the greatest tribute to his worth is found in the number of men—some young, some approaching middle age—who are heard to say, 'John Britton was like a father to me.' This world is the better for his coming. The void his passing has created cannot be measured now."

Mr. Britton was exceedingly human and service was his constant aim. He was peculiarly fitted to manage; being a leader, not a driver, and possessing a simplicity and kindliness of manner, he appealed to all with whom he came in

contact. Men came to him for counsel and friendly advice and at all times one was impressed with his moral and spiritual values. He had dignity and force of character, but with these also a keen sense of humor and a manner that was extremely approachable. His doors were closed to none. John Britton will be missed among those men who are doing things that are worth while. One writer happily characterized him as follows:

"The end of earthly things has come for John A. Britton. With his passing there has come to the people of San Francisco Bay region an abiding sense of personal loss.

"It is difficult to put into words the hold he had taken upon the hearts of the people of this community. Regret at interruption to a brilliant career and grief at the hushing of a loved voice are not confined to those who can speak of him out of a wealth of personal association. He was too big to have belonged to a few.

"Some one once said John Britton had the granite chin of a successful business man and the eyes of an artist. He was a man of the broadest sympathies, kindly and courteous, with a high character and integrity which was never questioned. Both inside and outside of the great organization he had helped to build are men and women who feel their lives have been made brighter and better by having known John Britton and being able to read aright the splendid lesson of his life.

"The theme necessarily must suffer at the hands of whoever undertakes briefly to pay adequate tribute to John Britton. It has been said, with much of truth, that it is not obvious why most of us are born, or indeed, why almost any one of us might as well not have been born at all. Occasionally, however, it becomes apparent, even to the least discerning, that a man is sent into the world with a particular work to perform. Such a man was John Britton. He brought to his life work high ideals and he consistently battled for those ideals which he believed would best promote the happiness and welfare of his fellow man.

"John Britton needs no mausoleum. His epitaph is engraved upon the hearts of all with whom he came in contact. He brought to his life work extraordinary mental qualities, a powerful mind, inspiring logic, and a reasoning power of high order. Of him it can truly be said: 'His life was gentle and the elements so mixed in him that nature might well stand up and say to all the world, "This was a man"'".

Mr. Britton was elected an Affiliate of the American Society of Civil Engineers on January 6, 1915.

ALFRED GEORGE COMPTON, Assoc. Am. Soc. C. E.*

DIED DECEMBER 12, 1913.

Alfred George Compton, the son of William and Elizabeth G. Compton, was born in London, England, on February 1, 1835. His early childhood was spent in London, and in his father's former home, the village of High Wycombe, a market town in Buckinghamshire.

In 1842, his father, who was a piano manufacturer, brought the family to America, the voyage lasting thirty days, and settled in New York City.

* Memoir compiled from information on file at the Headquarters of the Society and from data supplied by Theodore Belzner, Affiliate, Am. Soc. C. E.

Alfred George Compton attended the public schools of the City, where he was prepared for college. He entered the Free Academy (now the College of the City of New York) in January, 1849, and was a member of its first graduating class in July, 1853.

Following his graduation, he had intended to become a Civil Engineer, but he was offered a Tutorship in the College, which he accepted. From 1853 to 1869, he taught history, rhetoric, philosophy, Spanish, etc. This work was interrupted by the Civil War during which he was engaged on field and permanent fortifications and stereotomy. In 1869, he was appointed to the Chair of Applied Mathematics, which he held until his retirement in 1911. Professor Compton achieved great success in this Department and was especially interested in its work. In 1902, he was appointed Professor of Physics, and was Acting President of the College from December 1, 1902, to September 1, 1903.

Beginning in 1869, for eighteen years, he conducted a three-year post-graduate course in Civil Engineering work, outside his regular hours. This course was considered of the greatest value by his post-graduate students.

During the last twenty-one years before his death, Professor Compton superintended the preparation of textbooks for the Mechanical Department, and also the Manual Training Department.

In 1869, with the late Cleveland Abbe, he conducted an Eclipse Expedition to Sioux Falls City, Dakota Territory (then a hamlet of twenty houses), and reported it to the Cincinnati, Ohio, Observatory, and, in 1878, he led a party of students to Colorado, where he observed an eclipse which he reported to the Naval Observatory at Washington, D. C. He also recorded a transit of Mercury, and had been engaged in other astronomical work.

In spite of the fact that he led a busy life, Professor Compton found time to write the following books, "A Manual of Logarithmic Computation", "First Lessons in Wood Working", "First Lessons in Metal Working", "The Speed-Lathe", in collaboration with J. H. de Groodt, "The Engine Lathe", also in collaboration with J. H. de Groodt, "Some Common Errors of Speech", and "Shall and Will". He also contributed discussion* on papers on rainfall and the flow of streams presented before the Society.

He was a man of unusually strong personality. Perhaps no other teacher of his generation has exerted such a wide and lasting influence on the youth of New York City. He had genius as a teacher, and was able to hold the serious and undivided attention of his students, although his subjects were among those not usually considered popular. In addition to his work as a teacher, Professor Compton's services were always at the call of the College authorities. He was an accomplished linguist and was interested in music and literature. His love of Nature was an outstanding characteristic and his greatest pleasure and relaxation were long tramps through the woods.

He was married on June 10, 1874, to Miss Frances E. Feeks and was survived by a son, Alfred D. Compton, and two daughters, Madeleine and Mable G. Compton.

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* *Transactions*, Am. Soc. C. E., Vol. X (1881), p. 249.

He was a member of the American Institute of Electrical Engineers, the University Settlement Society, and the Century Association of New York.

Professor Compton was elected an Associate of the American Society of Civil Engineers on September 5, 1877.

GEORGE ADAM WEBER, Affiliate, Am. Soc. C. E.*

DIED MARCH 29, 1923.

George Adam Weber was born on December 13, 1848, in a log cabin in Como, Ill., which, at that time, was considered a frontier town. He received his early education in the public schools of Chicago, Ill., and, later, attended Williston Seminary at Easthampton, Mass., from which he was graduated. He then became a member of the Class of 1872 at Yale University.

Mr. Weber's greatest successes in business date from his invention of the Weber rail joint in 1888, and of the insulated joint in 1894. The Weber Rail Joint Manufacturing Company was organized in 1889, and made rapid growth under his vigorous direction.

In 1905, his Company, together with the Independent Railway Supply Company and Continuous Rail Joint Company of America, were merged into The Rail Joint Company. This amalgamation permitted Mr. Weber's retirement from active business and his later years were passed in the enjoyment of his home and friends. He died on March 29, 1923, at his winter home in Pasadena, Calif.

In his death, the brotherhood of railway equipment manufacturers lost a figure of real distinction, for Mr. Weber was not only the inventor of the Weber rail joints and one of the founders of the Rail Joint Company, but also a man of rare humor and humanity. Whether in the business and social life of New York City, at his home in Stamford, Conn., or Pasadena, golfing at Apawamis, Blind Brook, or Midwick, fishing at Catalina or at his camp, Sans Souci, in Quebec, he was youthful, companionable, and forceful. Few men have been so equally successful in business and in friendship.

He is survived by his wife, Annie Hoyt Weber, a son, W. Hoyt Weber, and three daughters, Mrs. J. P. Howe, Mrs. C. H. Luther, and Mrs. N. C. Sweet.

Mr. Weber was elected an Affiliate of the American Society of Civil Engineers on February 6, 1900.

* Memoir prepared by Percy Holbrook, Assoc. M. Am. Soc. C. E.